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PRELIMINARY INVESTIGATION - PHASE I
DESCRIPTION OF CURRENT CONDITIONS

HARBOR ISLAND
Seattle, Washington

June 6, 1985

# State of Washington
# Department of Ecology
# Remedial Action Division
# Office of
# Hazardous Substances and Air Quality

**Region 10**
**Superfund Records Center**

44070

Black & Veatch
Engineers-Architects

BAR Code
1088163

THE SEAL OF THE STATE OF WASHINGTON 1889

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## EXECUTIVE SUMMARY

A two-phased Preliminary Investigation is being conducted for WDOE to determine the current conditions at the Harbor Island "Superfund" site. This report presents the results of Phase I, which consists of a review of existing data. Collection of necessary additional data will be accomplished during Phase II.

The Harbor Island site is located approximately one mile southwest of downtown Seattle, Washington, where the Duwamish River flows into Elliott Bay. The site, or study area, includes Harbor Island and the adjacent commercial/industrial areas and waterways. Almost all of the land area of the site consists of filled tidelands constructed during the late 1800's and early 1900's using dredge spoils and hydraulic grading spoils. Since that time, the site has been used exclusively for commercial (bulk storage; port, rail and similar transportation) and heavy industry (secondary lead smelting, other secondary metal processing, and shipbuilding) activities.

The site has two major environmental issues. The first issue is lead contamination from previous operations of a secondary lead smelting facility on Harbor Island; concern about high levels of airborne lead from this facility resulted in the designation of Harbor Island as a Superfund site. The second issue is the known or suspected releases of significant quantities of hazardous substances from at least 12 facilities on Harbor Island and at least 8 facilities off Harbor Island, but within the boundaries of the study area (site).

The airborne lead problem has been mitigated by termination of the smelting operations and by paving several roadsides and parking lots on Harbor Island to prevent reintrainment of previously-deposited lead particulates. Recent data show the site is in compliance with ambient air quality standards for lead. site. However, the lead-contaminated soil near the smelting facility represents a potential environmental threat to aquatic resources (benthic, invertebrate, and fish). Data indicate that the upper half-inch of street dust and surface soil in some areas of Harbor Island may contain as much as 18 percent lead. Also, sediment samples taken from the Lander Street storm drains that collect runoff from the area around the smelter contained 0.6 to 36.8 percent lead. Further, sediment samples taken from the West Waterway near the Lander Street storm drain outfall contained elevated levels of lead.

Generally, more data is available about the lead smelter than about the other 19 facilities in the study area that are suspected/known to be sources of hazardous material releases. Considerable data exists for Wyckoff Company, a wood-preserving facility on Elliott Bay, which is the subject of litigation by regulatory agencies. Although very little data about Wyckoff was available during Phase I due to the ongoing litigation, data from the Florida Street storm sewer near Wyckoff indicated sediments contained elevated levels of arsenic and copper. At the other extreme, data for some facilities consist of only aerial photographs from 20 to 40 years ago, showing piles or ponds of unknown waste — such facilities have been subsequently closed. It is apparent that significant quantities (with respect to CERCLA) of hazardous materials have been released from several facilities at the Harbor Island site.

Existing data indicate the presence of elevated levels of several heavy metals and organic toxicants in the water column, sediment, and soils of the Harbor Island study area. The adverse environmental effects of these pollutants on certain biota have been demonstrated in various biological studies. Identification of the sources of the contaminants has not been conducted in most cases. Additional data collection will be necessary during Phase II to clarify the suspected contribution of the Harbor Island site.

# 1.0 INTRODUCTION

This section presents the scope of the Preliminary Investigation (PI), background information about the Harbor Island site and its environmental problems, and an overview of the report. Portions of this PI are similar to work that would be performed during a full scale Remedial Investigation (RI). Further, a cooperative agreement exists between the United States Environmental Protection Agency (EPA) and the State of Washington regarding the Harbor Island site. Therefore, this report is organized in the EPA format recommended for RI reports to facilitate review and coordination with future EPA remedial activities.[1]

## 1.1 PROJECT SCOPE

The Hazardous Waste Remedial Action Section of the State of Washington, Department of Ecology (WDOE), has contracted with Black & Veatch Engineers-Architects (B&V) to conduct a Preliminary Investigation (PI) of the Harbor Island site. The Harbor Island site is on the EPA National Priorities List (ranked number 426 of 538 sites) of uncontrolled hazardous waste sites, as a result of lead pollution.[2] Since 1980, remedial actions performed at the site by private (industry) and local government agencies have significantly reduced airborne lead hazards. Therefore, the purpose of the PI is to collect and review relevant existing data and generate any new data that is necessary to allow regulatory agencies (primarily WDOE and EPA) to determine if the site warrants further attention under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as "Superfund."

The PI is divided into two phases, with Phase I consisting of the following elements:

- o Gather and assess data relative to past site activities, waste disposal practices, and site conditions.
- o Conceptually define the nature and extent of contamination present.
- o Determine the necessity for further field data collection.
- o Develop a work plan to collect additional data, if necessary.

Phase II of the PI will consist of the actual field work required to collect and review any additional data. This report describes the results of the existing data collection, review, and interpretation activities of Phase I.

## 1.2 SITE BACKGROUND INFORMATION

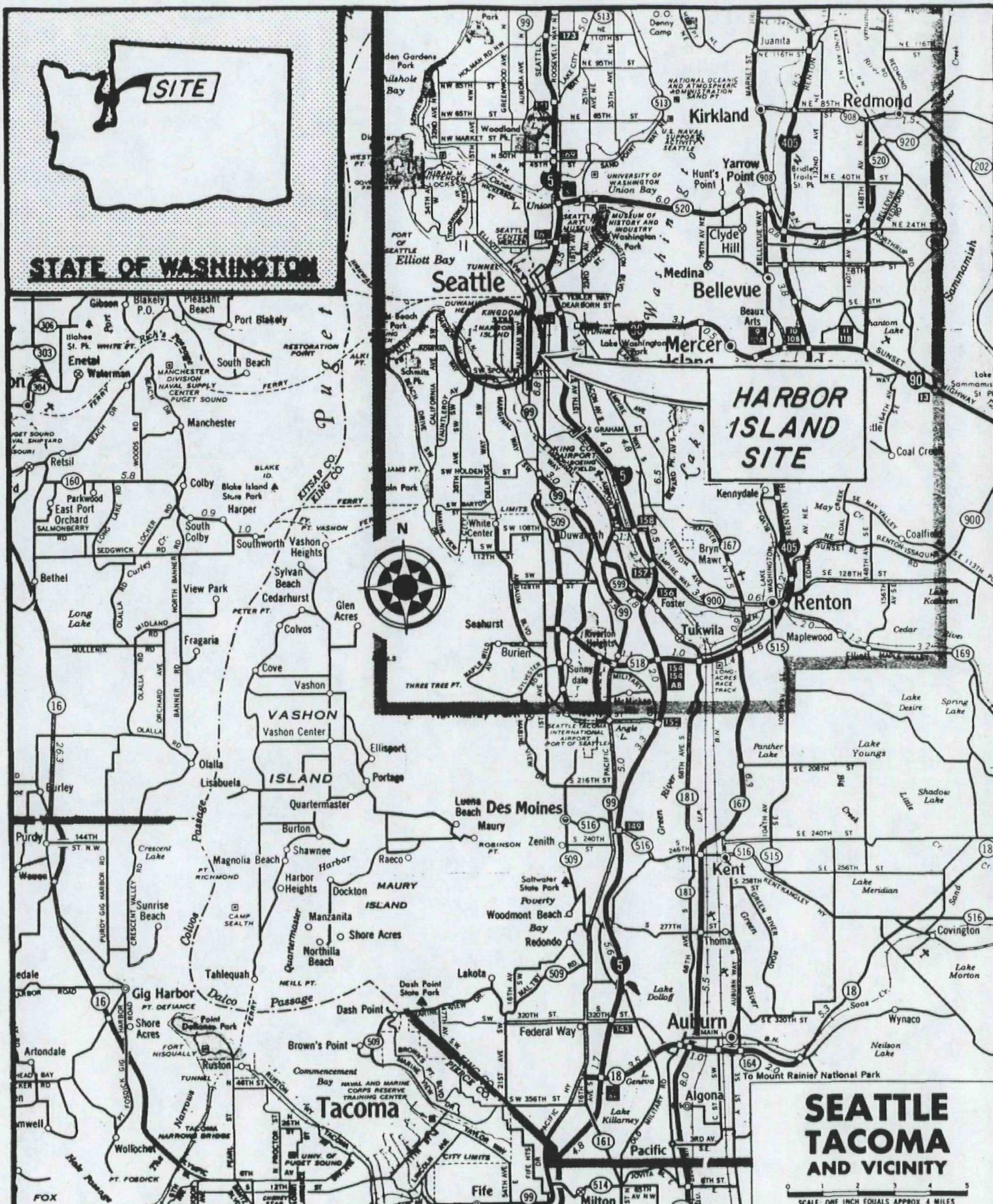
As shown on Figure 1-1 and Figure 1-2, the Harbor Island site is located approximately one mile southwest of downtown Seattle, where the Duwamish River flows into the southern edge of Elliott Bay. The site consists of Harbor Island; the commercial/industrial areas immediately adjacent to Harbor Island; and the Lower Duwamish River, East Waterway, West Waterway, and southern edge of Elliott Bay.

Harbor Island is a 455-acre man-made island that was constructed during the early 1900's in an area consisting of intertidal wetlands at the mouth of the Duwamish River. The island was built initially using sediments dredged to facilitate navigation in the lower Duwamish River and the West Waterway. Subsequently, debris from demolition and regrading projects in the Seattle area were used to complete island construction. Similar dredge and fill techniques were used to construct the commercial/industrial areas immediately adjacent to Harbor Island.[3,4,5]

The study area has been used for industrial and commercial purposes since it was built. In 1920, industrial development on Harbor Island consisted of Fisher Flour, Todd Shipyards, Puget Sound Bridge and Dredging Company Shipyard, and the East Waterway Terminal. Development continued through the World War II era, by which time the entire study area was essentially occupied by commercial/industrial facilities. Subsequent development has consisted of primarily property transfers, with the main new development involving expansion of the Port of Seattle facilities. In fact, the Port of Seattle constructed an additional 50-acre fill area on the northeastern corner of Harbor Island in 1966 (Terminal 18).[6]

## 1.3 NATURE AND EXTENT OF PROBLEMS

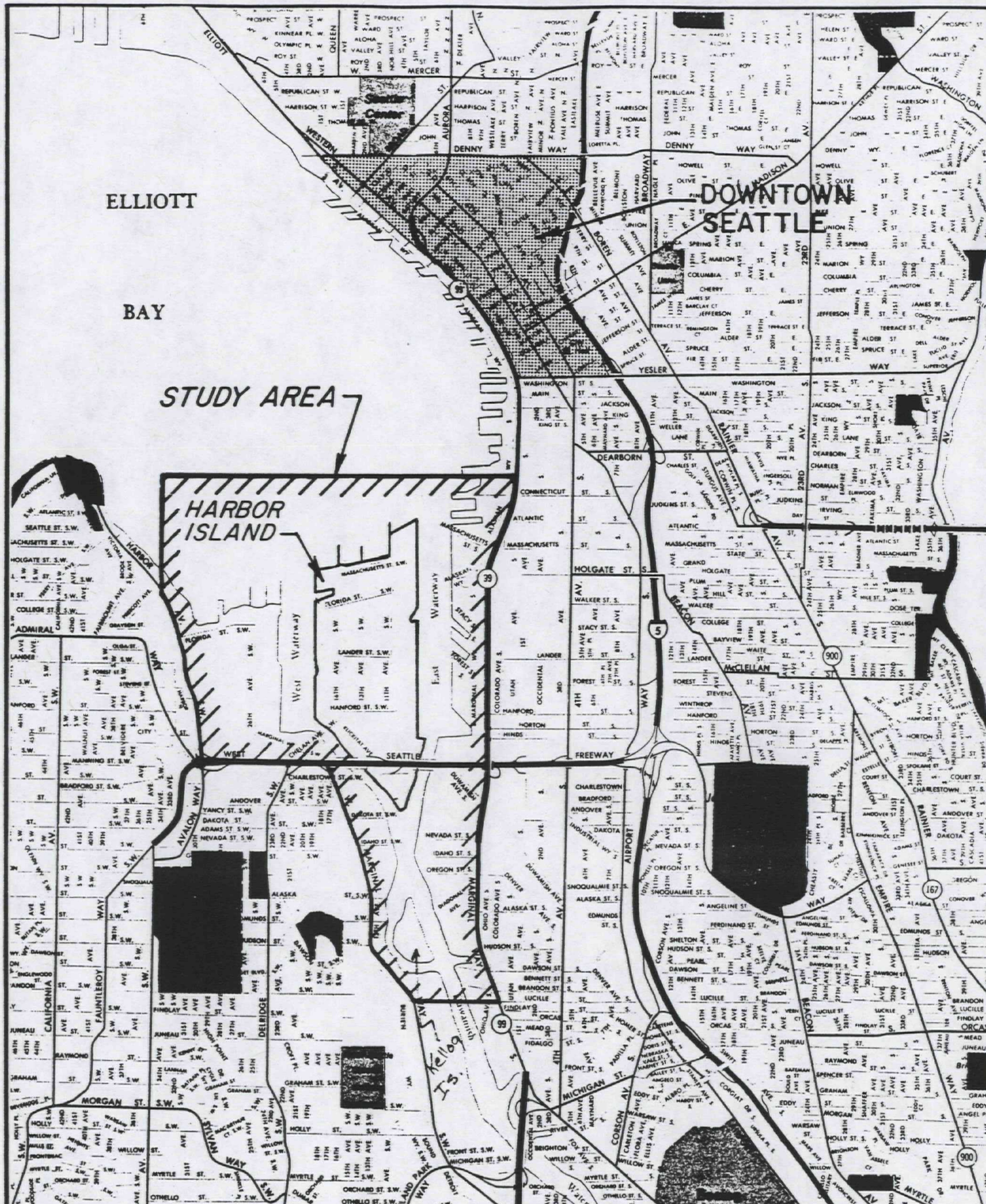
Generally, two environmental problems have been identified within the study area. First, there is the lead contamination problem that resulted in Harbor Island being designated a National Priorities List site. The second is




# LOCATION MAP

## PRELIMINARY INVESTIGATION - PHASE I
## HARBOR ISLAND
## SEATTLE, WASHINGTON

FIGURE 1-1




0 .25 .50 .75 1
SCALE IN MILES

## VICINITY MAP

N

# PRELIMINARY INVESTIGATION - PHASE I
# HARBOR ISLAND
# SEATTLE, WASHINGTON

FIGURE I-2

the wide variety of pollutant releases from numerous sources throughout the study area, not just on Harbor Island.

The lead problem was first recognized by the Puget Sound Air Pollution Control Agency (PSAPCA) in 1977 when an ambient air monitoring station (K60) located on Harbor Island indicated airborne lead levels of 2.34 micrograms per cubic meter ($ug/m^3$), exceeding the present national ambient air standard of 1.5 $ug/m^3$. The main source of the lead was reported to be the Quemetco (now SEAFAB) secondary lead smelting facility located on Lander Street, between 16th Avenue SW and 13th Avenue SW.[3] Subsequent implementation of air emission controls and dust controls at Quemetco, as well as paving of several parking lots and roadsides near the Quemetco plant have decreased lead concentrations in the ambient air.[7] In 1983, the Quemetco facility was sold to Bergsoe Metal Corporation, which discontinued lead smelting and refining operations. (Bersoe sold the facility to SEAFAB Metal Corporation in 1984.)[8] Present air quality on Harbor Island is in compliance with ambient standards for lead.[7]

However, the lead that accumulated in Harbor Island soils and sediments during the years prior to these improvements remains on the site. Surface soil samples (upper 0.5 inch depth) taken along 16th Avenue SW, 13th Avenue SW, and SW Lander Street by PSAPCA staff in 1979 and 1982 contained lead concentrations as high as 18 percent.[3] The roadside areas where the highest lead levels were found have been paved. Still, the concern remains whether the paved-over lead, as well as lead in lower concentrations in other areas of Harbor Island, could present potential hazards to human health or the environment through reintrainment into air or water media as a result of traffic, precipitation, or construction/demolition activities.

Another environmental problem in the study area consists of known and suspected releases of pollutants from at least 20 public and private facilities. Further information about these potential pollution sources is included in Section 3.[4,9]

Potential offsite pollutant releases are a very important consideration in determining whether the pollutant sources located on the site are, or could become, the cause of significant environmental/health hazards. At several locations outside the study area, industrial facilities and past waste disposal facilities are known or suspected to have released pollutants into surface water or ground water that subsequently passes through the Harbor Island site.[4,9] Therefore, knowledge of past practices and conditions in areas upgradient from the site is important to understanding the conditions at the site.

## 1.4 OVERVIEW OF REPORT

This report presents the findings of Phase I of the PI. Section 2.0 through Section 6.0 of the report describe various aspects of the current conditions at the site. Section 7.0 and Section 8.0 explain the potential or existing hazards to humans or the environment as a result of the current conditions. Specifically, Section 2.0 of the report describes the existing and historical land use, the natural resources, and the climatology of the site. Section 3.0 describes the known and suspected sources of pollutant releases on the site. Section 4.0 discusses the soils, geology, and groundwater hydrology of the study area while Section 5.0 presents the marine/estuary physical conditions and water quality, surface drainage, and sediment chemistry aspects of the site. Section 6.0 explains the historical as well as present air pollution considerations regarding lead. Section 7.0 presents data regarding suspected impacts of site pollution on aquatic biota, and Section 8.0 summarizes the potential public health and environmental impacts of the site. References cited in a section are numbered in the text and listed by number at the end of each section. All references cited, as well as all other information sources consulted, are listed in the Bibliography.

## 1.5 ACKNOWLEDGEMENTS

An interdisciplinary team of engineers, scientists, and technical specialists from B&V and its subcontractor, Parametrix, Inc., conducted the Phase I investigations and prepared this report. The team's data gathering efforts were facilitated by the assistance of staff at the U. S. Army Corps of Engineers, EPA, WDOE, Municipality of Metropolitan Seattle (METRO), City of Seattle, King County, PSAPCA, Port of Seattle, U. S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Department of Labor and Industry, Bethlehem Steel Corporation, and several agency consultants.

## 1.6 REFERENCES


1. JRB Associates, Remedial Investigations Guidance Document, Final Draft, prepared for US Environmental Protection Agency, October 17, 1984.

2. U. S. Environmental Protection Agency, "National Priorities List", Federal Register, Volume 49, Number 200, October 15, 1984.

3. CH2M-Hill, Inc., Ecology & Environment, Inc., Draft: Remedial Action Master Plan, Harbor Island, Seattle, Washington, prepared for US Environmental Protection Agency, October 4, 1983.

4. Harper-Owes, Duwamish Ground Water Studies, Waste Disposal Practices and Dredge and Fill History, prepared for Sweet, Edwards and Associates, Inc., March 1985.

5. P. Benoit, "The Man Induced Topographic Change of Seattle's Elliott Bay Shoreline from 1852 to 1930 as an Early Form of Coastal Resource Use and Management," Master's Thesis, University of Washington, 1979.

6. Marine Digest, Volume 57, Number 29, March 3, 1979.

7. A. Guillen, Black & Veatch, Conference Memorandum, Meeting with F. Austin, PSAPCA, Seattle, Washington, March 27, 1985.

8. Parametrix, Inc., Surface Impoundment Closure Plan, SEAFAB Metal Corporation, Seattle, Washington, November 1984.

9. METRO, Duwamish Industrial Non-Point Source Investigations, January 1985.

# 2.0 SITE FEATURES INVESTIGATION

This section describes the physical features, land use, and climatology of the study area (site). As shown on Figure 2-1 and Figure 2-2, the site consists of filled intertidal wetlands and islands at the mouth of the Duwamish River. Harbor Island and the adjacent fill areas were constructed during the late 1800's and early 1900's using dredge spoils that resulted from navigation improvements in the lower Duwamish River.[1] Additional fill materials from demolition and regrading activities in the Seattle area also have been used to further buildup the site.[2] The fill materials generally consist of silty sand;[3] Section 4.0 describes the nature of the fill material and the underlying soil/sediment.

## 2.1 LAND USE

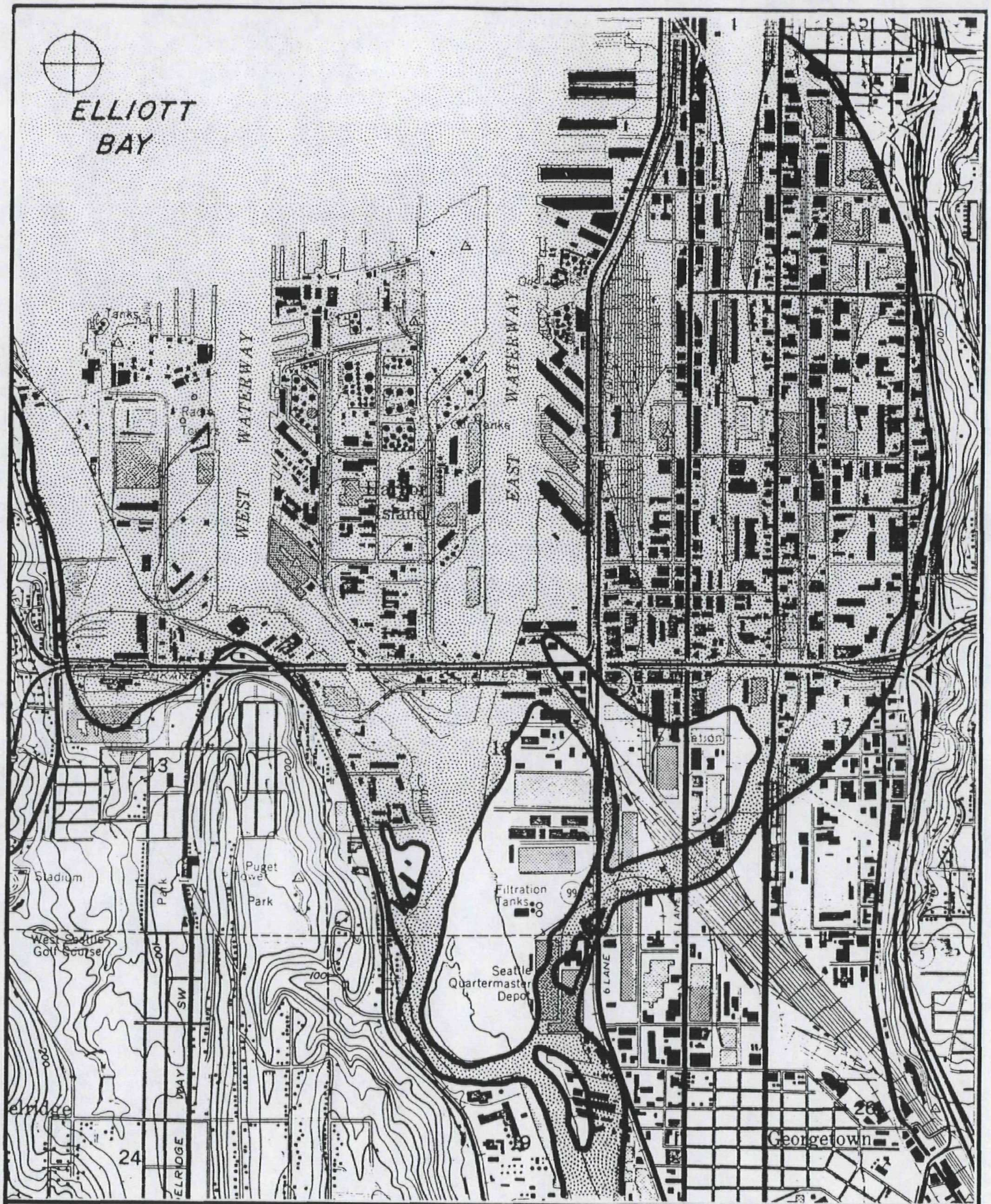
As shown in Figure 2-3, the site is a heavily developed commercial/industrial area. There are no residential sections within the study area, although residential areas border the site on the west and southwest sides, and the site is approximately one mile southwest of downtown Seattle. The primary land uses are shipping terminal and other transportation operations, ship building/repairing, material storage, and heavy manufacturing. The major commercial/industrial facilities located on the site are shown on Figure 2-4 and listed in Table 2-1.

## 2.2 NATURAL RESOURCES

The commercial and industrial development of the site has eliminated virtually any natural shoreland wildlife habitat. An exception is Kellogg Island, which has been designated as a wildlife preserve.[3,4] Although Kellogg Island has historically been used for log stockpiling and dredge spoil disposal the northern half of the island remains a relatively unspoiled salt marsh.[3,4] There are presently no active groundwater supply wells in the study area.[3]

## 2.3 CLIMATOLOGY

The climate of the study area is tempered by the nearby marine environment. Most air masses reaching the area are formed over the Pacific Ocean. Summers are relatively cool and dry, while winters are mild, with light rain occurring frequently. The prevailing wind is from the southwest in the fall and winter and from the northwest during spring and summer. Average annual precipitation is approximately 34 inches.[5]



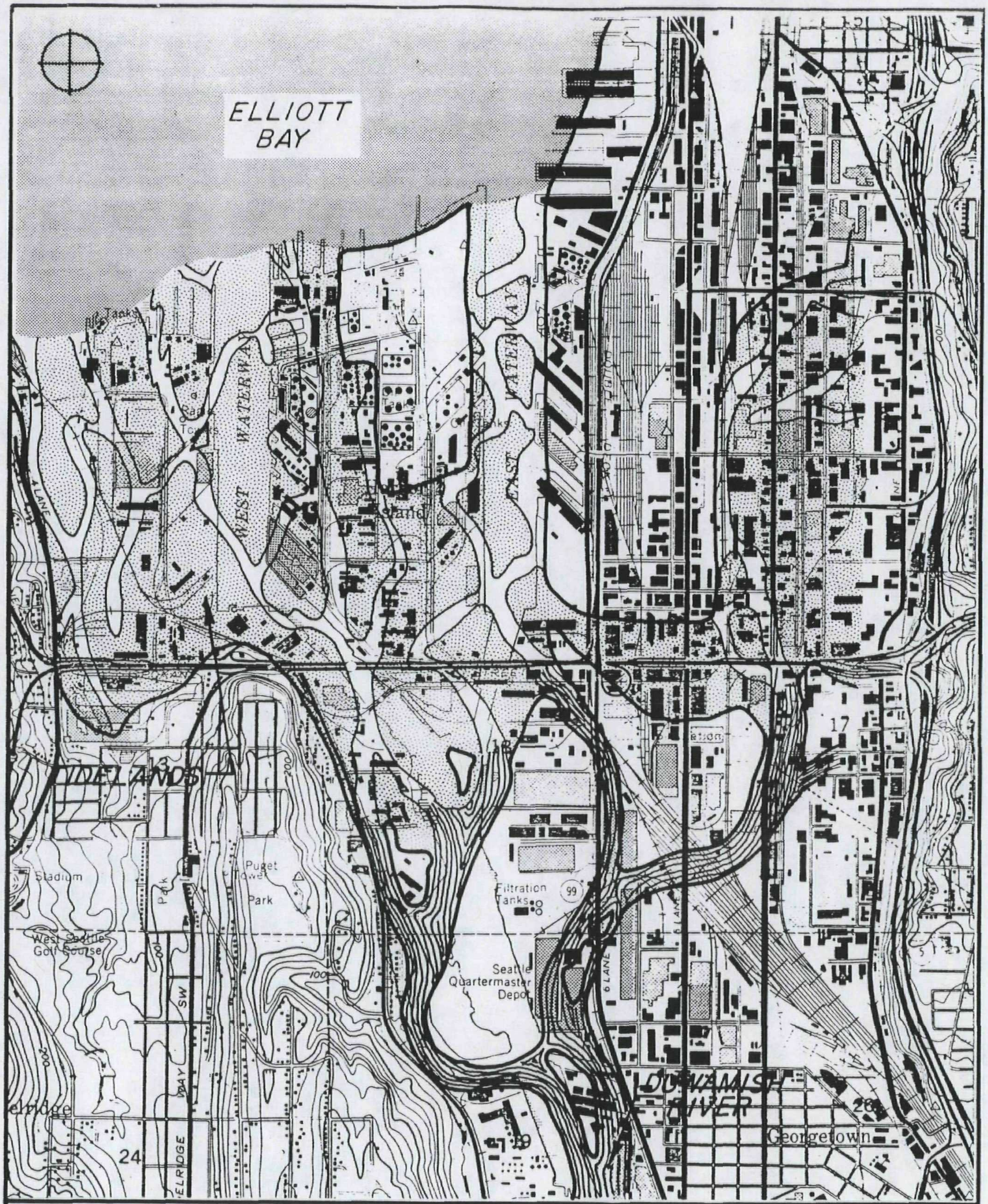

REF.: USGS

## 1854 STUDY AREA SHORELINE

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

SCALE: 1" = 2000'

FIGURE 2-1



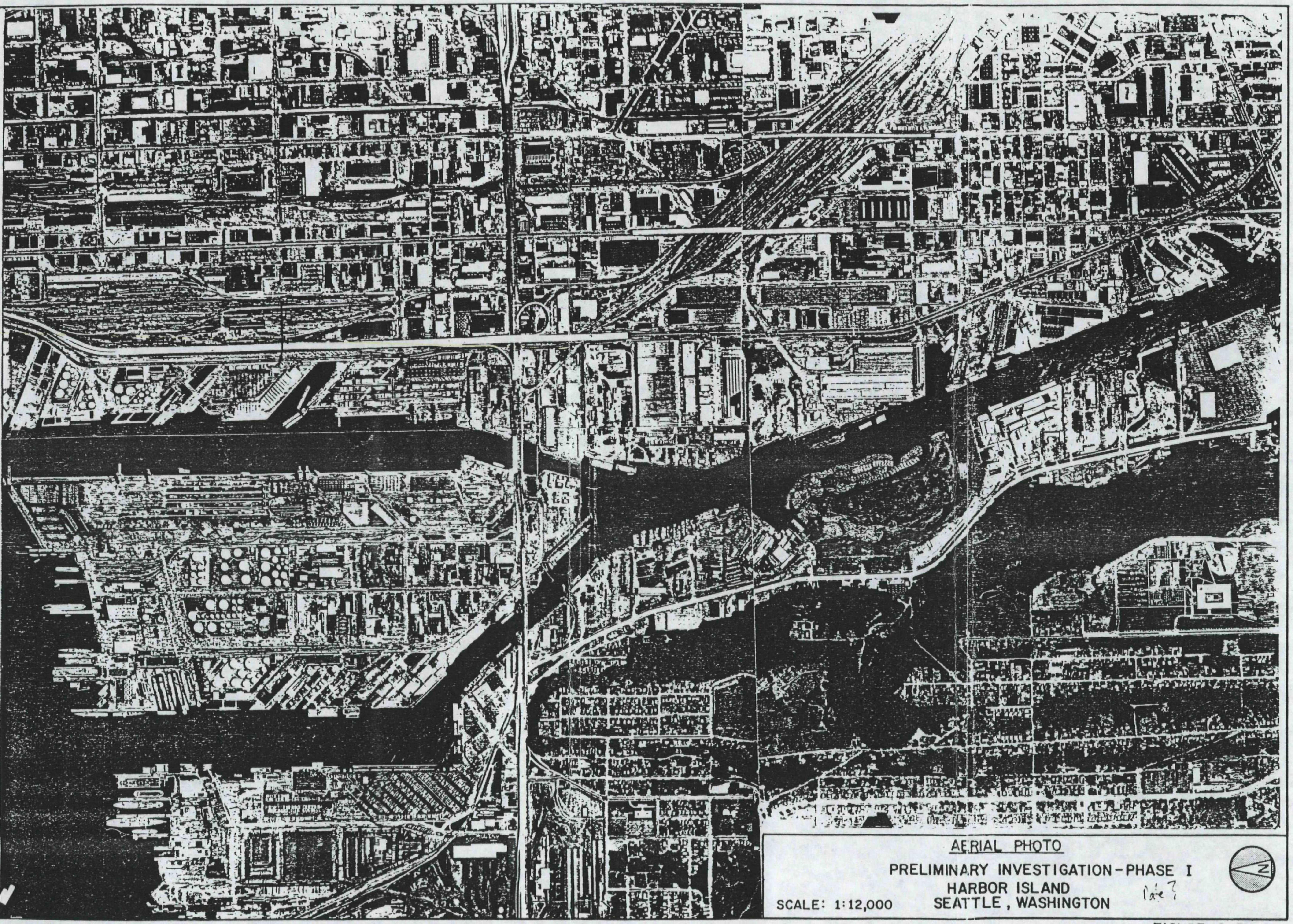

REF.: USGS

## 1909 STUDY AREA TIDELANDS

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

SCALE: 1" = 2000'

FIGURE 2-2



AERIAL PHOTO

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

Date?

SCALE: 1:12,000

FIGURE 2-3

TABLE 2-1. MAJOR FACILITIES IN STUDY AREA

| Figure 2-4 Reference Number | Facility Owner/Tenant |
|---|---|
| | On Harbor Island: |
| 1 | SEAFAB Metal Corporation |
| 2 | Seattle Iron & Metal Corporation |
| 3 | Shell Oil Company |
| 4 | Seattle Foundry |
| 5 | Pacific Resins & Chemicals, Inc. |
| 6 | Texaco, Inc. |
| 7 | Port of Seattle—Terminal 18 |
| 8 | Todd Shipyards Corporation |
| 9 | Lockheed Shipbuilding & Construction Company |
| 10 | Leckenby Structural Steel Company |
| 11 | Non-Ferrous Metals Company |
| 12 | Fisher Flouring Mills |
| 13 | Schorn National Lead |
| 14 | Atlantic Richfield Company |
| 15 | Port of Seattle — Terminal 102 (formerly U.S. Gypsum Company) |
| 16 | Port of Seattle |
| 17 | Liberty Equipment & Supply |
| 18 | V. R. McAlister (leased to F.S. Lang Manufacturing) |
| 19 | Union Pacific Corporation |
| 20 | R & U, Inc. |
| 21 | Wyatt Engineers |
| 22 | Port of Seattle (leased to Smith Berger Manufacturing) |
| 23 | Butler |
| 24-29 | Not assigned |

TABLE 2-1 (CONT'D). MAJOR FACILITIES IN STUDY AREA

| Figure 2-4 Reference Number | Facility Owner/Tenant |
|---|---|
| | Off Harbor Island: |
| 30 | Port of Seattle -- Pier 2 |
| 31 | Port of Seattle -- Terminal 105 |
| 32 | Port of Seattle -- Terminal 25 |
| 33 | Ideal Cement Company |
| 34 | Wycoff Company |
| 35 | Purdy Company |
| 36 | Port of Seattle -- Terminal 5 |
| 37 | Bethlehem Steel Corporation |
| 38 | City of Seattle Landfill (owned by Bethlehem Steel Corporation) |
| 39 | Port of Seattle -- Terminal 30 |
| 40 | Port of Seattle -- Terminal 106W |
| 41 | Standard Oil of California (Chevron) |
| 42 | Port of Seattle -- Terminal 107 |
| 43 | Port of Seattle -- Freeze Facilities |
| 44 | Port of Seattle -- Terminal 37 |
| 45 | Port of Seattle -- Terminal 106 |
| 46 | Port of Seattle -- Terminal 106E |
| 47 | National Fruit Canning |
| 48 | Pacific Reefer Fisheries |
| 49 | Lone Star Cement |

## 2.4 REFERENCES


1. Harper-Owes, Duwamish Ground Water Studies, Waste Disposal Practices and and Dredge and Fill History, prepared for Sweet, Edwards and Associates, Inc., Bellevue, Washington, March 1985.

2. CH2M-Hill, Inc., Ecology & Environment, Inc., Draft: Remedial Action Master Plan, Harbor Island, Seattle, Washington, prepared for U. S. Environmental Protection Agency, October 4, 1983.

3. Sweet, Edwards and Associates, Inc., Draft Report: Duwamish Ground Water Studies, prepared for METRO, March 31, 1985.

4. R. Carson, "Return of the River," Pacific Northwest, March 1985.

5. E. L. Phillips, Washington Climate for These Counties: King, Kitsap, Mason, and Pierce, Washington State University, January 1968.

# 3.0 HAZARDOUS SUBSTANCES INVESTIGATION

This section addresses the known and suspected sources of hazardous substance releases at the Harbor Island site. Existing information about the location, quantity, and composition of these materials is presented.

The site has been used almost exclusively for industrial and commercial activities since it was built near the turn of the century. For many years, large quantities of hazardous substances were released from the facilities located within the study area (site), because pollution control practices were not common until the past two decades.[1,2] Similarly, because documentation of pollution releases was not widely practiced until recently, little quantitative data exist regarding historical pollutant sources. However, existing data indicate a substantial number of present or recently closed facilities on the Harbor Island site have suspected or known releases of hazardous substances.

## 3.1 POLLUTANT SOURCES ON HARBOR ISLAND

Centrally located within the study area, Harbor Island was the focus of CERCLA - related activities to date. The primary pollutant of concern on Harbor Island has been lead, reported to be the result of previous operations at a secondary lead smelting facility currently owned by SEAFAB Metal Corporation.[3] Additional pollutant sources on Harbor Island could represent hazards to the environment or human health.[4]

### 3.1.1 SEAFAB Metal Corporation

SEAFAB currently owns a lead reclamation (from batteries) facility located between 16th Avenue SW and 13th Avenue SW, immediately south of SW Lander Street. (See Figure 2-4.) The lead releases of primary concern occurred prior to acquisition of the facility by SEAFAB in December 1983.[3,5] Previous owners of the facility included Bergsoe Metal Corporation (most recently); Quemetco, Inc. (RSR, Inc.); Bunker Hill Company; and Western Lead Company.[3,5]

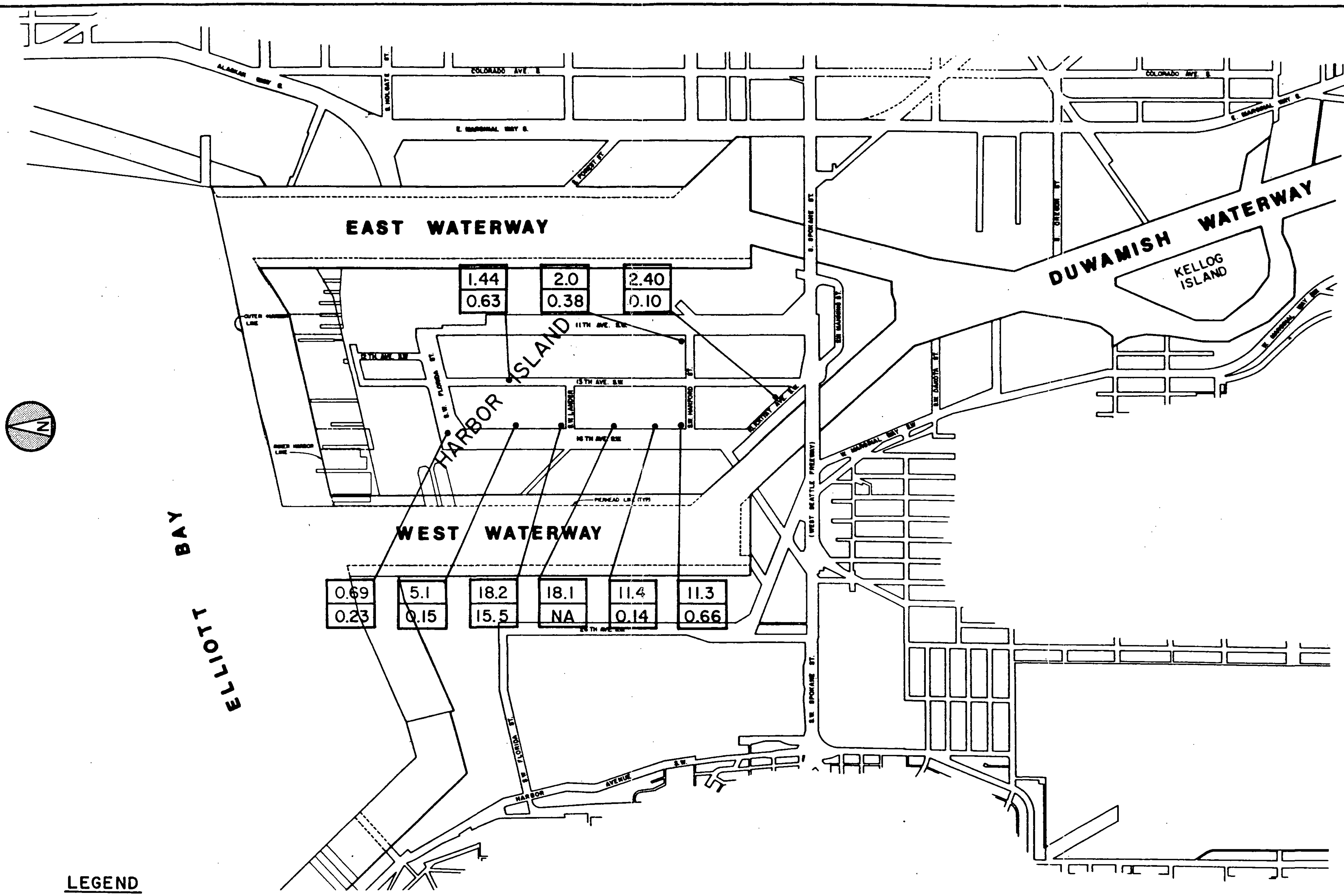
As discussed in more detail in Section 6.0 point source emissions and vehicle-related activities at the facility resulted in airborne levels of lead that exceeded present ambient air quality standards.[3] Although the problem of airborne lead on Harbor Island was first discovered in 1977, it has probably occurred since the facility began operation in 1935.[3] Analysis soil samples taken during 1979 and 1982 indicate that lead was present in very high levels (up to 18 percent) in ground surface dust in the immediate vicinity of the facility.[3] Subsequent operational and equipment modifications at the facility reduced lead releases from the plant site,[3,5] and several roadside areas and parking lots were paved to control reintrainment of lead-contaminated particulates.[6] Current air quality on Harbor Island is in compliance with applicable standards for lead (see Section 6).

Although the airborne lead situation appears to have been resolved, other environmental concerns about the SEAFAB facility remain. These concerns are the potential hazards from the lead particulates that have accumulated on and around Harbor Island over a period of nearly 50 years and the potential subsurface discharge of lead and other heavy metals from a seepage pond or other areas of the SEAFAB facility.

The extent to which lead has accumulated in Harbor Island surface soils is relatively unknown, as is the potential for the lead particles and lead-contaminated soil to migrate into water systems. The only available data regarding lead concentrations in surface soil are the samples of street dust and soil taken by PSAPCA in 1979 and 1982,[7] as shown on Figure 3-1.[3] Grab samples of sediments in storm drains taken along SW Lander Street by METRO in March 1984 found lead concentrations of 0.6 to 36.8 percent.[8]

The only available groundwater quality data from Harbor Island is from one monitoring well located on SEAFAB property. This well (identified as MW-1 in the SEAFAB surface impoundment closure plan) was constructed in 1981 along the western edge of the SEAFAB property and extends to a depth of 18 feet below grade. A groundwater sample taken from this well in May 1984 was found to contain 0.01 milligrams per liter (mg/l) of dissolved lead.[5]

Process wastewater and area runoff at SEAFAB is also a potential source of hazardous material releases. Prior to 1975, untreated process wastewater and area runoff from the plant was discharged to an impoundment located in the southeast corner of the property.[4] From 1975 through approximately February




LEGEND

LEAD LEVEL (%), 1979

LEAD LEVEL (%), 1982

SOURCE: CH2M-HILL

SCALE: 1" = 1200'

SURFACE SOIL LEAD LEVELS

PRELIMINARY INVESTIGATION - PHASE I

HARBOR ISLAND

SEATTLE, WASHINGTON

FIGURE 3-1

1982 the process wastewater was pretreated and discharged to a seepage pond located where the surface impoundment had been previously.[4,5] Data from 1976 through 1982 (as shown in Table 3-1) indicate levels of lead as well as cadmium, copper, nickel, and zinc in the pretreated water discharged to the seepage pond consistently exceeded EPA water quality criteria for saltwater acute toxicity.[4,5] The volume of process wastewater discharged was reported to be approximately 1.3 million gallons annually.[5]

### 3.1.2 Seattle Iron and Metal

Since 1950, Seattle Iron and Metal Company has operated a metal salvage facility on Harbor Island.[9] The facility occupies the southern portion of the block bordered by 11th Avenue SW, 13th Avenue SW, and SW Hanford Street. (See Figure 2-4.) Two pollutant release problems are known to exist at Seattle Iron and Metal. One problem is seepage of potentially contaminated rainwater into the ground at an unpaved scrap iron storage area — this area also collects run-on from surrounding streets. The other problem is overflow of wire-washwater into the storm drain system. Chemical characteristics of the washwaters, as shown in Table 3-2, include concentrations of copper, lead, and zinc several orders of magnitude higher than EPA saltwater acute toxicity criteria.[1,4] The plant is reported to be in the process of developing a system to pretreat the washwater then discharge to the METRO sanitary sewer.[1]

### 3.1.3 Value Plating and Metal Finishing

The Value Plating Facility is located on 11th Avenue SW, south of SW Hanford Street. (See Figure 2-4.) Value Plating discharged process wastewater onto the ground behind the facility from 1970 when it began operations until 1978 when it connected to the METRO sanitary sewer. The chemical characteristics of Value Plating wastewater discharged to METRO, as shown in Table 3-3, significantly exceed EPA saltwater toxicity criteria.[4]

TABLE 3-1. CHARACTERISTICS OF WASTEWATER DISCHARGED TO SEEPAGE PIT AT SEAFAB (QUEMETCO) FACILITY

| Sample Date | Concentration (mg/l) Cadmium Av | Cadmium Pk | Chromium Av | Chromium Pk | Copper Av | Copper Pk | Nickel Av | Nickel Pk | Lead Av | Lead Pk | Zinc Av | Zinc Pk |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/6/76 | 0.15 | 0.58 | 0.01 | 0.02 | 0.94 | 13.0 | 0.45 | 0.79 | 1.0 | 4.1 | 1.0 | 1.9 |
| 11/10/77 | 0.30 | - | 0.06 | - | 1.2 | 1.5 | 0.48 | - | 3.6 | 5.6 | 1.3 | 1.9 |
| 11/11/77 | - | - | - | - | 1.3 | 1.4 | - | - | 5.7 | 7.0 | 1.2 | 1.3 |
| 2/21/78 | - | - | - | - | 0.18 | - | - | - | 3.6 | - | 0.26 | - |
| 6/13/79 | - | - | - | - | 1.0 | 2.[illegible] | - | - | 0.15 | 0.30 | 0.33 | 0.93 |
| 6/14/79 | 0.95 | - | 0.04 | - | 3.8 | 8.4 | 0.49 | - | 3.1 | 4.9 | 3.4 | 6.9 |
| 7/12/79 | 1.0 | - | 0.02 | - | 1.6 | - | 0.59 | 0.73 | 0.75 | 1.3 | 0.57 | - |
| 7/13/79 | - | - | - | - | - | - | 1.2 | 1.7 | 0.64 | 1.8 | - | - |
| 10/28/80 | 1.0 | 1.5 | 0.09 | - | 3.4 | 4.9 | 0.16 | - | 3.3 | 5.9 | 3.5 | 5.5 |
| 6/2/81 | 0.96 | 1.1 | <0.04 | <0.04 | 2.3 | 3.2 | 0.56 | 0.64 | 2.3 | 4.1 | 0.81 | 0.98 |
| 6/3/81 | <0.01 | - | <0.04 | - | <0.02 | - | 0.02 | - | 0.04 | - | <0.01 | - |
| 7/22/81 | 0.07 | - | 0.02 | - | 1.0 | - | 0.39 | - | 0.88 | - | 1.3 | - |
| 10/22/81 | 2.1 | - | 0.06 | - | 4.0 | - | 1.1 | - | 4.4 | - | 0.79 | - |
| 11/24/81 | 1.7 | 2.0 | <0.02 | <0.02 | 2.8 | 7.6 | 1.1 | 1.3 | 3.4 | 7.1 | 3.0 | 5.8 |
| 11/25/81 | 1.0 | 1.2 | <0.02 | <0.02 | 4.7 | 7.4 | 0.55 | 0.61 | 2.7 | 4.6 | 1.0 | 1.1 |
| 2/10/82 | 2.2 | - | 0.02 | - | 7.1 | - | 0.63 | - | 0.49 | - | 0.55 | - |
| EPA Acute Saltwater Criteria | 0.059 | | 10.2 ($Cr^{+3}$)<br>1.26 ($Cr^{+6}$) | | 0.023 | | 0.14 | | 0.668 | | 0.17 | |

Source: References 4 and 5.

TABLE 3-2. CHEMICAL CHARACTERISTICS OF WASHWATER FROM SEATTLE IRON AND METAL FACILITY

| Sample Date | Concentration (mg/l) | | | | | |
|---|---|---|---|---|---|---|
| | Copper | Lead | Zinc | Nickel | Cadmium | Chromium |
| 1974 | 0.760 | 0.800 | 0.440 | 0.140 | - | - |
| 1984[a] | 1600 | 74 | 21.9 | 0.73 | 0.156 | 0.60 |
| 1984 | 248 | 62 | 12.5 | 0.3 | 0.105 | 0.25 |
| 1985 | 18.2 | 11.5 | 1.19 | <0.2 | <0.4 | <0.2 |
| 1985 | 16.2 | 4.25 | 1.41 | <0.2 | <0.4 | <0.2 |

[a] Sample taken from settling pit; all other samples taken from drain line.

Source: Reference4.

TABLE 3-3. CHEMICAL CHARACTERISTICS OF WASTEWATER FROM VALUE PLATING AND METAL POLISHING FACILITY

| Parameter | Concentration (mg/l) | EPA Saltwater Acute Toxicity Criteria (mg/l) |
|---|---|---|
| Cadmium | 0.23 | 0.059 |
| Chromium | 95 | 10.2($Cr^{+3}$), 1.26($Cr^{+6}$) |
| Copper | 55 | 0.023 |
| Nickel | 209 | 0.140 |
| Lead | 0.42 | 0.668 |
| Zinc | 6.3 | 0.170 |

Source: Reference [4].

### 3.1.4 Golden Penn Oil Company

Located on the east side of 13th Avenue SW, between SW Lander and Hanford Streets, Golden Penn was a waste solvent recycling facility that was reported to have operated a waste impoundment onsite.[4] However, the facility is now closed and no existing data are available.

### 3.1.5 Other Facilities

Several other facilities on Harbor Island are known or suspected to have released hazardous substances. Among these are two unnamed facilities and six existing industrial facilities.

The first unnamed facility is a liquid disposal area identified from 1961 aerial photographs. The facility was located in an area bordered by SW Massachusetts Street, 13th Avenue SW, SW Florida Street, and 12th Avenue SW — now a rail transhipment area.[4]

The second unnamed facility was a small industrial plant with piles of white waste material onsite. Identified in a 1940 aerial photograph, the facility was located on the east side of 16th Avenue SW, midway between SW Lander Street and SW Hanford Street. By 1961, the site had been closed.[4]

Shell Oil Company has several petroleum storage tanks located on Harbor Island. It has been reported that Shell has constructed wells to recover leaked/spilled petroleum products; however, no data are available.[1]

Texaco also has a tank farm on Harbor Island for bulk storage of petroleum products. It has been reported that tank truck washwater from the facility has been discharged without adequate treatment, although current practices reportedly have corrected this problem by discharging to the sanitary sewer.[1]

Todd Shipyards and Lockheed Shipbuilding are reported to have allowed sandblasting material and paint overspray to enter the West Waterway. Subsequently, their facilities and procedures reportedly have been modified to prevent and/or minimize recurrance.[1]

Both the Leckenby Structural Steel and Non-Ferrous Metals, Inc. facilities on Harbor Island were reported to have unacceptably high pollutant levels in their wastewaters.[1] The Leckenby Steel facility has closed and is being considered for purchase by the Port of Seattle.[1,9] The only available detail about Non-Ferrous Metals was that sediment from a catch basin near the facility contained excessive levels of heavy metals.[1]

## 3.2 POLLUTANT SOURCES OFF HARBOR ISLAND

### 3.2.1 Wyckoff Company

The Wyckoff Company wood preserving facility is located on Elliott Bay, on the western side of the study area. (See Figure 2-4.) The facility treats wooden poles with preservatives (creosote, pentachlorophenol, and copper - arsenate salts) in pressurized kilns. Only limited data about Wyckoff were available from the regulatory agencies during Phase I due to pending litigation. [1,4,10,11,12] However, available data indicate abnormally high levels of metals especially copper and arsenic) and organics in soil around the Wyckoff site and storm drain sediment. [1,4,12,13]

Significant concentrations of organic toxicants were found in sediment samples taken in 1984 from a storm drain system manhole and catch basin in Florida Street adjacent to the Wyckoff site.[12] Toxicants found included 220 to 350 mg/l of polycyclic aromatic hydrocarbons (PAHs); particularly



mg/l = ppm

flouranthene, pyrene, and chrysene; and elevated concentrations of phenol and chlorinated phenols (pentachlorophenol, orthocresol, 2,4-dichlorophenol, and 2,4,6 - trichlorophenol).[12]

### 3.2.2 Purdy Company

The Purdy Company metal recycling facility is located at 2929 SW Florida Street, near the northwest corner of the site.[4] The Purdy facility has handled scrap transformers in the past and waste oil (believed to contain PCBs) has been spilled onsite.[1] Only limited data about the Purdy facility were available during Phase I because of the pending litigation regarding nearby Wyckoff Company.[4] However, sediment samples taken during 1984 from a storm drain manhole along Florida Street near the Purdy facility contained 1,050 mg/l of PCBs.[12]

### 3.2.3 West Seattle Landfill

From 1939 through 1966, the City of Seattle operated a landfill on the west side of the study area, located on property owned by King County and Bethlehem Steel Corporation. The facility encompassed approximately 20 acres bounded by Harbor Avenue SW, SW Hanford Street, the railroad tracks on the east, and SW Florida Street. Although the facility was used primarily for municipal refuse, it is believed to have received industrial wastes.[4]

### 3.2.4 Seattle Steel Company

The Seattle Steel Company (previously Bethlehem Steel) fabricates and galvanizes steel at a facility located on both sides of SW Spokane Street, between Harbor Avenue SW and Delridge Way. From the mid-1950's through mid-1970's, the facility disposed of waste acids and solids at a waste pile/landfill located near the Seattle landfill and at a slag dump located along SW Andover Street, between 28th Avenue SW and 26th Avenue SW.[4,14] Bethlehem Steel conducted groundwater studies at the Seattle landfill waste pile as part of a closure plan.[14] These studies indicated that water qaulity of the uppermost aquifer did not exceed National Interim Primary Drinking Water Standard (NIPDWS) for cadmium (0.01 mg/l) and lead (0.05 mg/l), although shallow groundwater contained 0.01 to 0.05 mg/l cadmium and 0.26 to 0.79 mg/l lead.[14]

### 3.2.5 Ash Grove Cement

The Ash Grove Cement facility, located along the east bank of the Duwamish Waterway just south of Harbor Island, stores a number of by-product materials onsite prior to using them in cement - manufacturing. These materials are reported to include slag from the Asarco smelter in Tacoma, coal, and coal fly ash. Plant runoff and wastewater are stored in an unlined surge pond prior to reuse. Analyses of the surge pond water are shown in Table 3-4.[4]

TABLE 3-4. CHEMICAL CHARACTERISTICS OF SURGE POND WATER FROM ASH GROVE CEMENT FACILITY

| Parameter | Concentration |
| --- | --- |
| pH | 10.8 |
| Copper | 0.1 mg/l |
| Zinc | 0.13 mg/l |
| Iron | 2.3 mg/l |
| Chromium | 0.35 mg/l |
| Lead | 0.56 mg/l |
| Conductivity | 225 umhos |
| Hardness | 120 mg/l |

Source: Reference 4.

### 3.2.6 Chevron Oil Company and GATX

The Chevron Oil Company petroleum storage facility (now owned by the Port of Seattle) is located directly east of Harbor Island, along the East Waterway. The Chevron tank farm and/or the adjacent GATX tank farm are believed to be the location of petroleum spills and/or leaks. A petroleum recovery program is reported to be operating at the Chevron facility. (See Table 4-5 and Table 4-6 for soil contamination data).[15]

### 3.2.7 Ideal Cement Company

The Ideal Cement Company facility is located on the west bank of the Duwamish Waterway, immediately south of Kellogg Island. The facility manufactures Portland cement. Washwater from kiln and truck washing operations at the facility flows to a seepage pond onsite. Ideal also has a kiln dust disposal site (landfill) located along West Marginal Way South, at South Hudson Street.[4]

## 3.3 DREDGE SPOIL DISPOSAL AREAS

As previously discussed, most of the land area in the Harbor Island study area was constructed during the late 1800's or early 1900's using dredge spoil. Dredge spoil also has been used extensively in more recent construction of several Port of Seattle terminal facilities within the study area. These recently dredged materials are of concern from an environmental perspective because they probably contain accumulated toxicants if they were dredged from heavily polluted areas of the Duwamish River. Dredge spoils from the lower Duwamish River are known to have been used as fill in the construction of Port of Seattle Terminals 5, 18, 30, 105, and 107.[4,15,16] Dredge spoils from the lower Duwamish River also have been disposed of on Kellogg Island.[4]

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# 4.0 HYDROGEOLOGIC INVESTIGATION

This section describes the geology, soils, and subsurface hydrology of the Harbor Island study area.

## 4.1 GEOLOGY

The study area is located on the Duwamish River valley floor of the central Puget Lowland, a large topographic basin extending from the Cascade Mountains to the Olympic Mountains. It is characterized by distinctive glacially derived soils (drift) and landforms. At least four glacial episodes are recognized in the Puget Lowland. During each episode the land was sculpted by glacial ice and soils were deposited. In addition, the Duwamish River itself has played a distinctive role in the geology of the study area.

The most recent glacial episode, the Vashon Stade of the Frasier Glaciation, began about 15,000 years, ago as a lobe of ice pushed south into the Puget Lowland. Three to four thousand feet of ice are estimated to have covered the study area during this glaciation.[2] This glaciation is significant in that it is believed that the present configuration of Puget Sound was largely sculpted by the action of this glacial episode.[3] The depth of the trough left by this glaciation in the ancestral Duwamish River valley is unknown, but a natural fill characterized by deltaic soils and floodplain silts are present in the river valley.[4]

Geologically, the Duwamish River has been characterized as a mature river. Since the early 1900's the Duwamish River valley has undergone some significant modifications such as filling, channel relocation and channel deepening. Prior to modification by man, most of the study area was actually characterized as marine and intertidal.[5]

The total depth of soils in the study area varies due to an inferred fault, downthrown to the north, which traverses the site from east to west.[6] At the north end of the study area, soils are inferred to extend to a depth of over 3,600 feet. At the south end of the study area, soils are inferred to extend to as depth of less than 800 feet.[7] No surface expression of this feature is evident. Danes and other[8] have interpret this feature to be a double fault and have identified several earthquake epicenters in its vicinity.

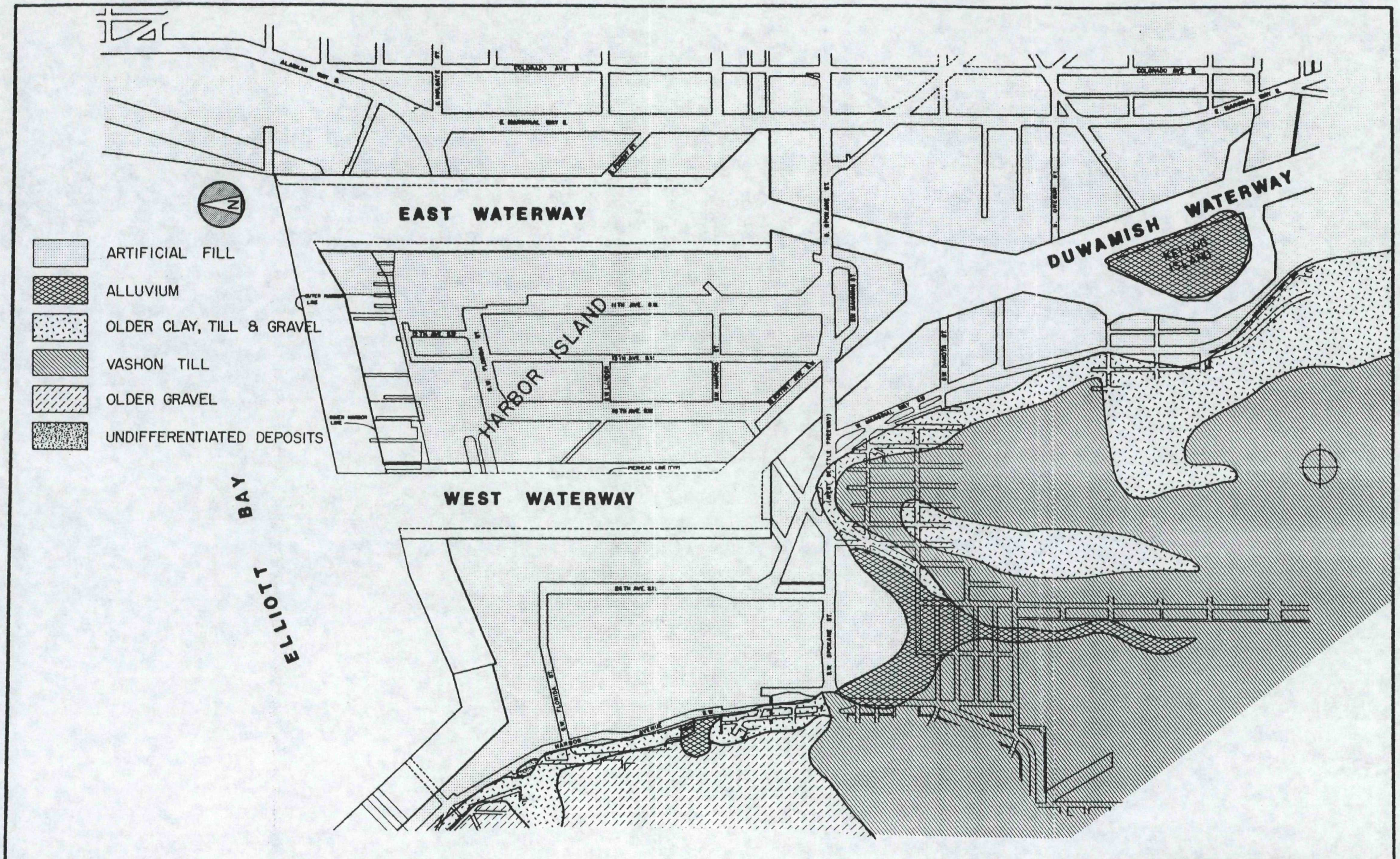
Shallow fluvial and estuarine soils in the study area are primarily derived from glacial soils. Predominant soil types reported by investigators include sands, silty sands, sandy silts, silts and clays. Also, bedload contributions from bedrock areas to the south have resulted in soils containing sands presumably derived from volcanic or sedimentary bedrock and coal fragments from the Palmer and Black Diamond area.[9]

Deeper soils may include other soil types characteristic of glacial drift including glacial till, outwash and recessional sands and gravels, and mixed or stratified deposits of clays, silts, sands and gravels. The deeper soils deposits that predate the Vashon Stade of the Frasier Glaciation are more consolidated by the weight of the ice than those soils which have since filled the Duwamish River channel.

The surficial geology of the study area has been characterized largely as fill.[10] Other geologic units identified include alluvium, beach deposits, glacial till deposited during the Vashon glaciation and other glacial deposits pre-dating the most recent glacial episode.[11] The surficial geology of the study area is presented on Figure 4-1.

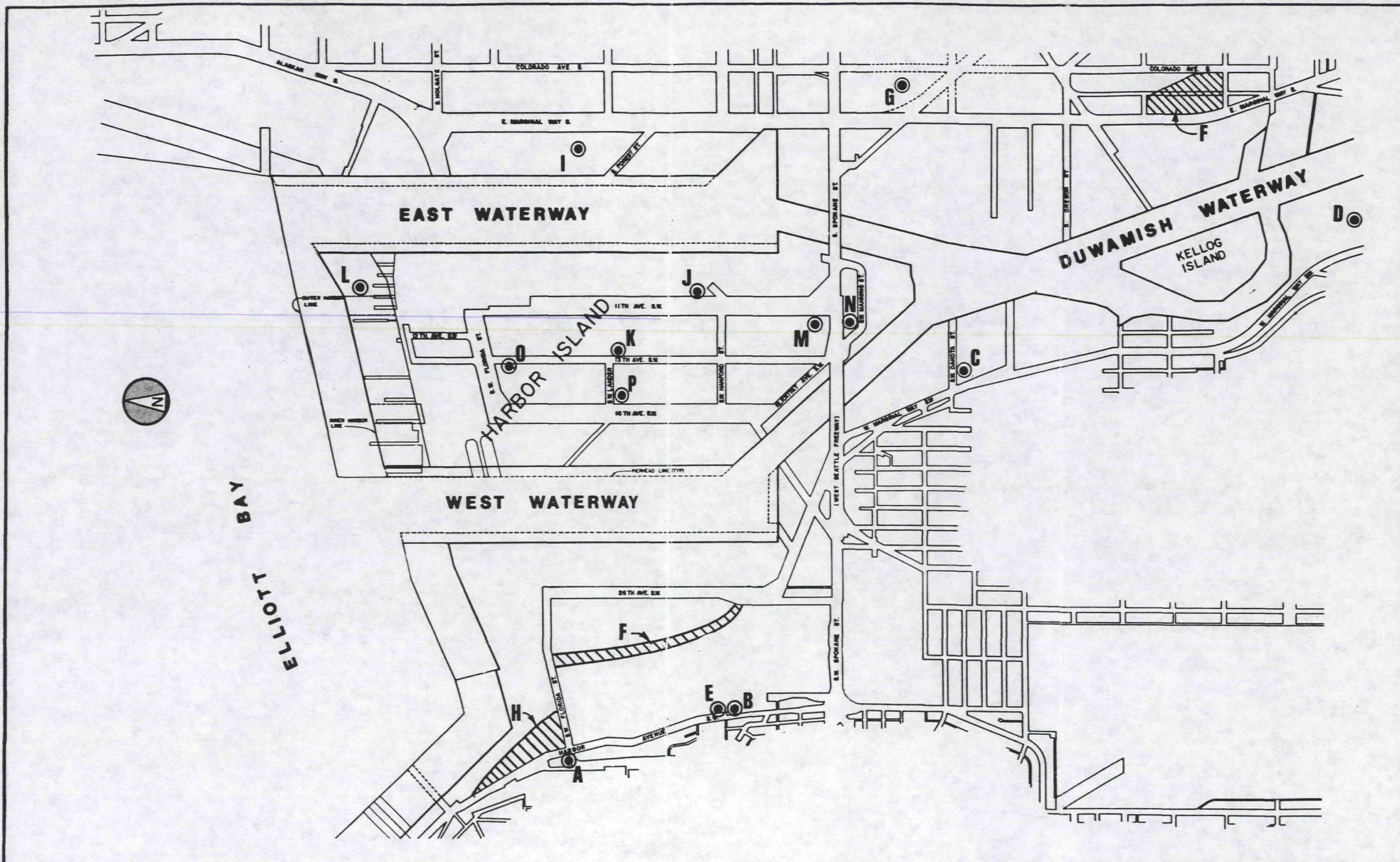
Since filling activity began along the Duwamish River, a significant amount of new land area has been added to the Duwamish River basin which has also resulted in significant changes in shoreline configuration.[5] (See Figure 2-1 and Figure 2-2.) The primary sources of fill material have been from dredge spoils and from hydraulic sluicing of soils from Beacon Hill to the west. Fill soils are generally silts and sands.

Many of the fine-grained soils in the study area (both natural and fill) have an affinity to attenuate cations from groundwater by adsorption onto clay particles. This has not been well verified in the study area by specific investigations but is a generalization based upon the properties of fine grained soils such as those encountered in the Duwamish River basin. The




SCALE: 1" = 1200'

SURFICIAL GEOLOGY
PRELIMINARY INVESTIGATION-PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON




(REFER TO TABLE 4-1 FOR INVENTORY)

SCALE: 1" = 1200'

LOCATION OF SOIL INVESTIGATIONS

PRELIMINARY INVESTIGATION - PHASE I

HARBOR ISLAND

SEATTLE, WASHINGTON

FIGURE 4-2

affinity of fine-grained sediments to adsorb pollutants were also reported in a similar industrialized estuarine river basin in New Jersey.[12]

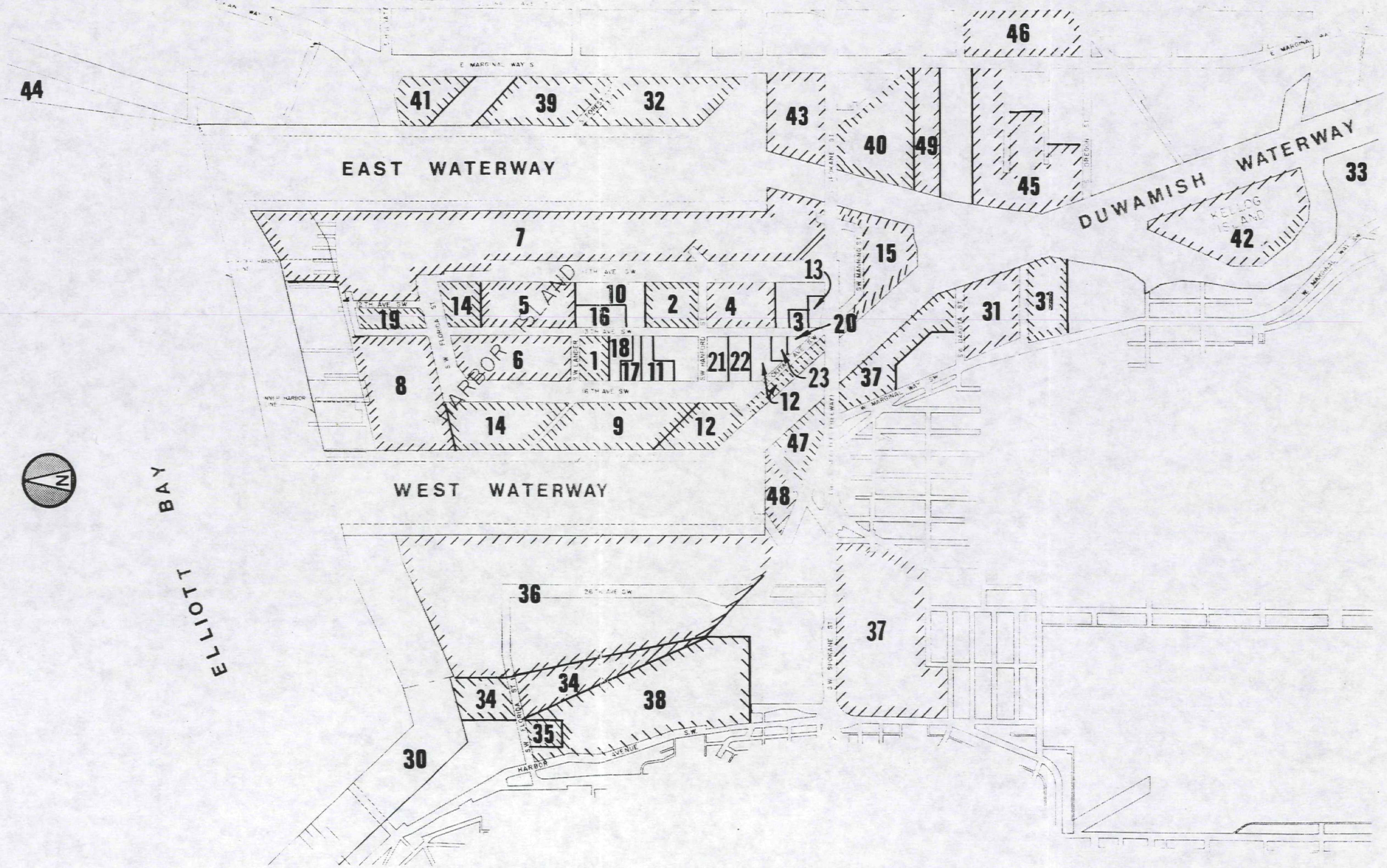
Geologic conditions in the study area are complex and difficult to correlate to a great degree of accuracy. This is due to the geologic history of the area and the lack of specific data on filling history. Prior to intervention by man, the study area encompassed the mouth of the Duwamish River and adjacent intertidal areas. A great amount of natural channelization within the river and intertidal environment, accompanied by scour and deposition, left a sequence of soils that are unique to each specific location. General soil types have been identified and are consistent as a group. Sweet, Edwards and Associates have recently correlated geologic data from borings across the study area.[11] Their report is the most comprehensive compilation of the geology of the study area available. Placement of fill in the study area is not well documented as to specific character of source material. In addition to the fill from Beacon Hill and dredge spoils there has also been filling in the area in the form of excavation and backfill of utility trenches and foundations.

## 4.2 SOILS

Sweet, Edwards and Associates[11] identified eighteen sites as being potential sources of pollution in the study area. Of these, information was available regarding soil chemistry at three of the sites. Actual sampling and analytical testing on most of the sites has not been done and the reports of possible pollution are relatively poorly documented.

Several soil chemistry investigations have been completed in the study area. Figure 4-2 shows the locations of site specific soils investigations in the study area which were available and reviewed for this study. The investigations reviewed are listed on Table 4-1. The most comprehensive for the purpose of this study is that performed for METRO by Converse Consultants.[13]

Table 4-1 outlines some investigations in which soil samples were taken and analyzed for potential pollutants. These studies demonstrate that at the sites investigated there is verifiable contamination of soils indication of industrial activity. Most of the studies were performed to evaluate the risk



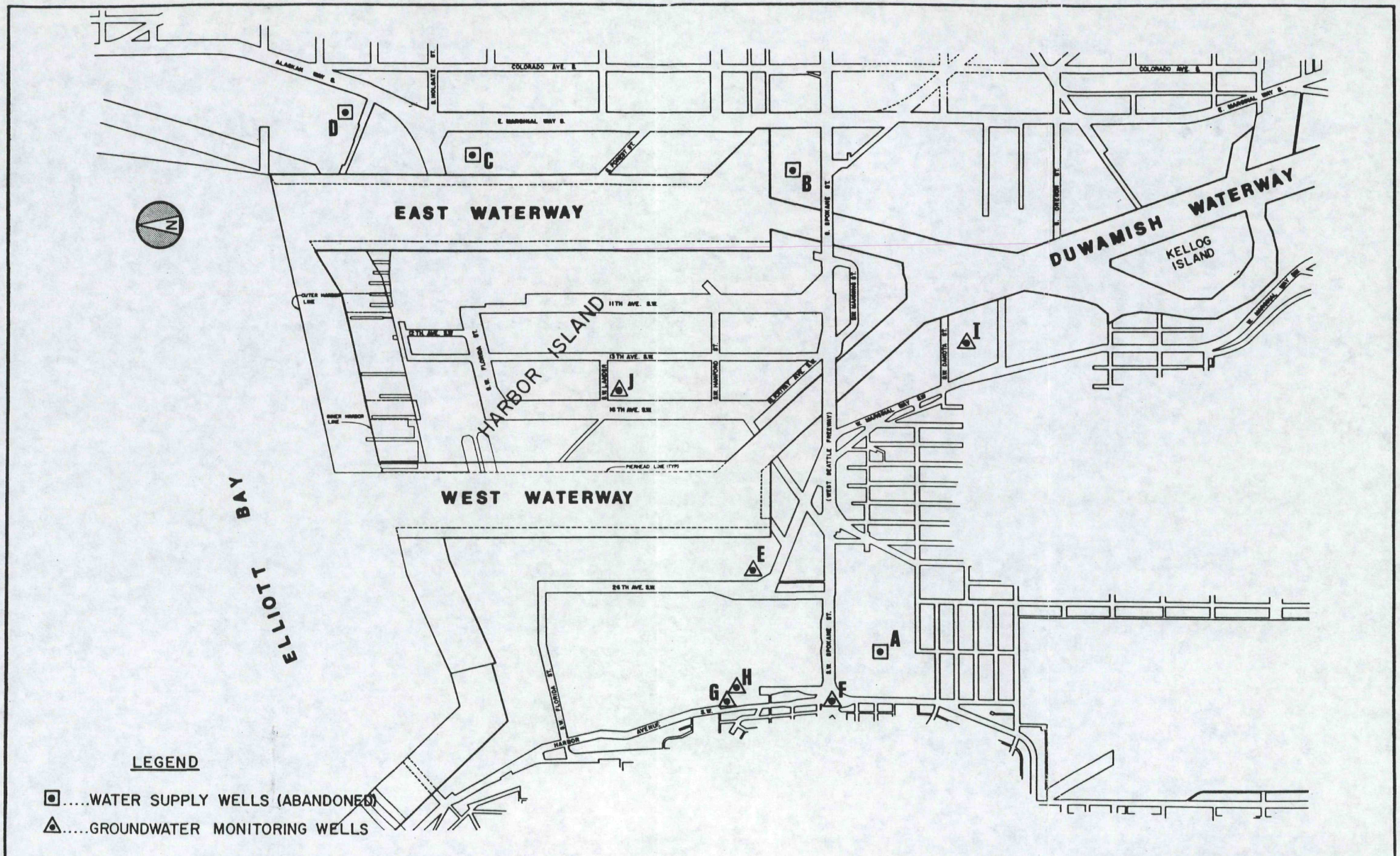

- REFER TO TABLE 2-1 FOR LIST OF FACILITIES

SCALE: 1" = 1200'

MAJOR FACILITIES IN STUDY AREA

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

FIGURE 2-4




(REFER TO TABLE 4-2 FOR INVENTORY OF WELLS).

SCALE : 1" = 1200'

WATER WELL LOCATIONS

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

FIGURE 4-3

of exposure of workers to soils as might be encountered during construction activities at a particular site. Due to the complex and varied history of the study area it is difficult to extrapolate the findings at any one site across the entire study area. Table 4-2 summarizes the parameters of laboratory analysis of the soils at locations investigated.

TABLE 4-1. INVENTORY OF SOIL INVESTIGATIONS (See Figure 4-2)

| Site | Description | Reference |
|---|---|---|
| A | METRO- RETS* Boring D564 | (18) |
| B | METRO- RETS* Boring DM555 | (18) |
| C | METRO- RETS* Boring D489 | (18) |
| D | METRO- RETS* Boring D414 | (18) |
| E | Bethlehem Steel (16 sample holes) | (19),(20) |
| F | Port of Seattle - Terminal 5 | (21) |
| G | Port of Seattle - Terminal 106E | (22) |
| H | Port of Seattle - Pier 2 | (23) |
| I | Port of Seattle - Terminal 30 | (24) |
| J | Seattle City Engineering | (27) |
| K | Seattle City Engineering | (27) |
| L | Seattle City Engineering | (27) |
| M | Seattle City Engineering | (27) |
| N | ABKJ | (21) |
| O | Seattle City Engineering | (27) |
| P | SEAFAB Metal Corporation | (28) |
| Q | Puget Sound Air Pollution Control Authority | (29) |

*RETS = Renton Effluent Transfer Station

TABLE 4-2. SUMMARY OF SOIL ANALYSES

| Site* | Analysis Parameters |
|---|---|
| A-D | Oil & grease, total solids, pH, TOX, TOC, phenol, cyanide, metals, and screening for volatiles, BAN & pesticides. |
| E | Lead and Cadmium. |
| F | EP toxicity, total PAH and HH, fish and rat bioassay, priority pollutants and pH. |
| G | Priority pollutants, total phenols, total cyanide, EP toxicity, organic vapor measurements. |
| H | Metals, total cyanide and phenols, organic screening, priority pollutants, organic vapor measurements. |
| I | EP toxicity, priority pollutants, organic vapor measurements. |
| J-O | None |
| P | Lead and Cadmium |
| Q | Lead |

*See Table 4-1.

A brief summary of each soil investigation and findings is presented below:

Sample Sites A-D

Six soil borings were placed along the proposed alignment of METRO's Renton Effluent Transfer System (RETS) pipeline. The borings were located on both public right-of-way and privately owned property. Within the study area, soil and water samples from locations A through D were screened to locate potentially contaminated soil. It was determined from the analysis of samples that soil from locations A, B and C had the greatest contamination potential. Sample location B is located in the identified area of the West Seattle Landfill. The sample indicated oil and grease concentration of 1,400 mg/kg and was the highest concentration observed in all samples obtained for METRO's study. Table 4-3 outlines some results of the sampling obtained within the Harbor Island study area for the METRO RETS study. The water samples described in Table 4-3 may have been taken during drilling operations and do not necessarily reflect groundwater quality. Chemical residues in these samples were detected including volatile organics (VOA), base and acid neutral (BAN) compounds, pesticides, phenol, cyanide and heavy metals. The pollutant screening for VOA, BAN and pesticides did not identify specific chemicals but rather indicated the possible presence of hazardous compounds. BAN compounds were found in measureable quantities in all the borings. VOAs were detected in two borings, one of which was Site B in the study area. Pesticides were detected only in Boring DM-555 (Site B).13

TABLE 4-3. SELECTED RESULTS OF METRO RETS POLLUTANT SCREENING

| | Site C | | Site B | |
|---|---|---|---|---|
| | Boring D489 | | Boring Dm-555 | |
| | Water | Soil | Water | Soil |
| Volatiles | <1ppm | ---- | 36ppm | 36ppm |
| Base/Acid Neutrals | 36ppm | ---- | 80ppm* | 48ppm |
| Pesticides | <1ppm | ---- | 2.9 ppm | <1ppm |
| Cyanide | ---- | 3.3 mg/kg* | 0.028ppm | ---- |

*Highest concentration found.

## Sample Site E

A number of samples were obtained presumably from an area used for the storage of electric arc furnace slag on the property of Bethlehem Steel. The samples were analyzed for lead and cadmium. Lead and cadmium were selected for analysis since these metals were the basis for designation of the slag as a hazardous waste. Information in WDOE files did not include a description of the locations where the samples were taken and information was not available concerning whether or not the samples were taken from waste materials or soils.[14] Since it is not clear as to the location or source of the sample (waste or soils) the results of the analyses are not included here.

## Sample Site F

This site, the Port of Seattle Terminal 5, was investigated by CH2M-Hill as the result of complaints during excavation for a sewer alignment during construction of a road. Numerous samples were obtained from this area and from soils removed from the site. The study was conducted on the premise that the site consisted of two areas of contamination; the south end primarily oil contamination and the north end contaminated with various industrial wastes, most likely wood-treating wastes.[15]

Generally, samples collected from the trench excavation area indicated the presence of detectable concentrations of organic contaminants such as pyrene, fluoranthene, phenanthrene, anthracene and napthalene. Results of the total PAH analysis (initial screening) ranged from 0.02 percent to 1.5 percent. Throughout the site, arsenic, beryllium, copper, lead, nickel, zinc and total cyanide were detected. The cyanide concentrations were particularly high ranging from 2.0 to 6,600 ppm. Oil and grease content of samples ranged from 0.03 to 0.57 percent. Further investigations determined that the low solubility of the samples was consistent with insoluble iron-cyanide compounds. These conditions would not be expected to result in leaching of cyanide into groundwater.[15]

Soil samples in the area did not classify as hazardous waste. The results of the E.P. Toxicity analysis indicated that a majority of samples contained non-detectable concentrations. Several samples indicated E.P. Toxic metal concentrations well below the hazardous waste criteria[15]

## Sample Site G

Site G was investigated by Rittenhouse Zieman, Inc. for the Port of Seattle. Samples were obtained in and around Terminal 106E, a warehouse storage operation. Detectable quantities of arsenic, chromium, copper, nickel and zinc were apparent in the soil. Additional leachate testing contained no detectable concentrations of the metals. On the assumption that the samples are representative of the site conditions, the contaminants in the surficial soils were determined to be in non-hazardous concentrations.[16]

## Sample Site H

Site H was sampled by Dames and Moore for the Port of Seattle Pier 2 West Yard Development. The area is located north of Florida Street and east of Harbor Avenue SW, bordered on the east by the Burlington Northern Railroad. Previous land use in the area sampled includes retail lumber and scaffolding businesses, fuel oil and coal distribution, metal salvage operations and a vacant area previously owned by the Burlington Northern Railroad.[17]

Detected concentrations of cadmium, copper, lead, zinc and cyanide in soils were determined by Dames and Moore to be elevated above expected background levels. Selected results of the analyses are shown on Table 4-4.

TABLE 4-4. SELECTED LAB ANALYSIS RESULTS FROM PORT OF SEATTLE - PIER 2 STUDY

| Parameter | Concentration Range (ppm) |
|---|---|
| Cadmium | 0.16 - 7.3 |
| Copper | 32.0 - 200.0 |
| Lead | 2.0 - 170.0 |
| Zinc | 68.0 - 280.0 |
| Cyanide | 0.3 - 99.0 |

Source: Reference 17.

The organic compound analysis indicated that for most samples, the concentrations were below the detection limit. The single highest contaminant concentration was bis 2 - ethylhexyl phthalate, a common plasticizer, ranging from <500 ppb to a high concentration of 20,400 ppb.[17]

Sample Site I

This site, Terminal 30, was sampled by Hart-Crowser and Associates for the Port of Seattle. The site was previously operated as a petroleum tank farm. The presence of free petroleum in soil and groundwater and the presence of other pollutants were indicated by field observations and laboratory analysis of soils. Recovery of petroleum from the groundwater surface is currently is progress. Organic vapor measurements were taken and priority pollutant analyses were performed. Evaluation of the analyses of soils from the site concluded that the excavated soil would likely not be classified as a dangerous waste but that additional testing such as fish bioassays would be required to confirm this. Some of the organic compounds detected in the soil include chloroform, tetrachloroethylene, phenanthrene, napthalene, toluene, acenaphthene, flourene, diethylphthalate, and flouranthene; many of which are petroleum derivatives. Metals including arsenic, lead, zinc and nickel were detected in elevated concentrations above an assumed background concentration.[18] Table 4-5 and Table 4-6 summarize data from these studies.

Sample Sites J-O

Soil borings taken at various locations on Harbor Island indicate that the general subsurface conditions of Harbor Island include 3 to 5 feet of a brownish gray silty fine to medium sand hydraulically filled. This has shell, wood chips, plank and occasional sandy silt seams.[27]

The fill overlays a layer of dark gray fine to medium saturated sand with some silt and organic materials. This layer is approximately 80 feet in thickness and it is an alluvium deposit.

Below the fill and alluvium deposits the fluvial-marine and the glacial deposits are found; these consist of silty sands to sandy silts with scattered areas containing thick interbeds of silty clay followed by reworked and lacustrine sediments and till.[11]

Sample Site P

This site, SEAFAB Metal Corporation, was the location of a surface impoundment. A soil sample taken 12 feet below the base of the surface impoundment was tested by the EP Toxicity extraction procedure, and indicated lead levels of 0.38 mg/l and cadmium levels of 0.12 mg/l. A closure plan was prepared and a decontamination plan was submitted to WDOE.[28]

Sample Site Q

During 1979 and 1982, the Puget Sound Air Pollution Control Authority took samples from the upper one-half inch of surface soil (dust) around the lead smelter on Harbor Island. Lead concentrations in these samples were as high as 18 percent.[29]

TABLE 4-5. TERMINAL 30 SHALLOW SOIL CONTAMINATION ANALYSES

| Sampling Zone | Organic Vapor Readings[a] Test1[b] | Test2[c] | Detected Organic Chemicals (concentration in ug/kg) | Detected Metals[d] |
|---|---|---|---|---|
| 1 | 5-10 | 10-50 | Chloroform(5)<br>Tetrachloroethylene(2)<br>Phenanthrene(1,200)<br>4,4 - DDE(3) | Arsenic(29)<br>Lead(82)<br>Zinc(7) |
| 2 | 3-5 | 45-460 | Fluoranthene(1,200)<br>Pyrene(1,300)<br>Beta BHC(5) | Lead(8)<br>Nickel(7) |
| 3 | 2-9 | 45-350 | None detected | Nickel(7) |
| 4 | 1-8 | 15->300 | Chloroform(8) | Arsenic(20)<br>Cadmium(7)<br>Lead(118)<br>Zinc(14) |
| 5 | 4-110 | 60->475 | Cloroform(370)<br>Tetrachloroethylene(39)<br>Toluene(380)<br>Ethylbenzene(100)<br>O-xylene(310)<br>P-xylene(120)<br>Gamma - BHC (lindane)(37)<br>4,4 - DDT(15)<br>Alphaendosulfan(60)<br>Total Cyanide(3) | Arsenic(15)<br>Lead(245)<br>Mercury(8)<br>Silver(5.0)<br>Zinc(15) |
| 6 | 5-88 | 35->490 | Chloroform(5)<br>Benzene(55)<br>Pyrene (1,200)<br>2-Methylnaphthalene(1,500) | Arsenic(10)<br>Lead(78)<br>Nickel(5)<br>Zinc(8) |

[a]Values shown are number of times greater than background level.
[b]Test 1 using H.Nu Photoionization Analyzer, Model PI 101, calibrated for benzene.
[c]Test 2 using Gastechtor Hydrocarbon Surveyor, model 1238, calibrated for methane.
[d]Values shown are number of times greater than background levels.

Source: Reference 18.

TABLE 4-6. TERMINAL 30 SOIL BORING CONTAMINATION DATA

| Sample Depth(ft) | Detected Organic Chemicals (concentration in ug/kg) | Detected Metals[a] |
|---|---|---|
| 0.5 - 3 | Naphthalene (1,500)<br>Acenaphthene (840)<br>Fluorene (600)<br>Phenanthrene (2,100)<br>Pyrene (1,000)<br>2-Methylnaphthalene (840)<br>Beta BHC (5) | Lead (7)<br>Nickel (5) |
| 5 - 8 | Toluene (800)<br>Naphthalene (11,000)<br>Fluorene (5,500)<br>Phenanthrene (9,300) | None |
| 12 - 5 | Diethylphthalate (2,300)<br>Beta BHC (2) | None |
| 19 - 25 | Beta BHC (2)<br>Gamma BHC (3) | None |

[a]Values shown are number of times greater than background levels.

Source: Reference 18.

## 4.3 GROUNDWATER

The primary aquifer of concern in the study area is a shallow aquifer within the alluvial and floodplain sediments of the Duwamish River valley. The depth, extent and flow characteristics of this aquifer occur at an elevation corresponding to the level of the Duwamish River. Shallow groundwater flow is probably influenced by localized zones of preferential flow through fill materials. Deeper flow within this same aquifer is presumed to be along the axis of the valley toward Elliott Bay.[11] Site specific investigations have provided localized characterization of the aquifer. Groundwater recharge to the area is derived from infiltration in adjacent upland areas, from overland flow to low-lying areas where infiltration occurs and from direct infiltration of precipitation. Although not confirmed within the study area, a vertical upward regional gradient probably exists within the low-lying portions of the lower Duwamish Basin. Hart-Crowser [19] in a comprehensive hydrogeologic evaluation of a site in Georgetown, to the south of the study area, did identify a vertical upward gradient in the uppermost, shallow aquifer.

Several studies have confirmed a relationship between the level of the Duwamish River (which is subject to tidal influences) and groundwater levels in wells in the shallow aquifer. Harding Lawson Associates[20] noted responses in groundwater monitoring wells at Terminal 105 of over six feet during a change of about eight feet in the Duwamish River. Similar responses were also noted by Anderson and others [21] in observation wells installed for the geotechnical design of the West Seattle Bridge.

Deeper, poorly understood, localized aquifers are present within the older unconsolidated sediments beneath the valley floor alluvium and flood plain deposits. Four groundwater supply wells are on record in the study area.[22] None of these wells are currently in use. A well drilled on Bethlehem Steel property in 1924 encountered three aquifers between 97 and 472 feet. It was reported in 1963 that the well was not in use. A well drilled for San Juan Fish Packaging Company to a depth of 240 feet was never used. The date the well was drilled was not reported. The well was reported to be incrusting, containing flammable gas and hydrogen sulfide.[22] The source or nature of this condition was not reported but this type of condition may be naturally occurring. A well drilled for the Elliott Bay Mill Company to a total depth of 1550 feet was never used due to insufficient yield.[22] A well drilled for Arden Farms in 1926 to a depth of 232 feet encountered a one foot thick zone of water bearing material. The well was reported to have been "destroyed".[22] No information was available as to methods of abandonment of the wells. The locations of these water wells are shown on Figure 4-3.

There is no current groundwater withdrawl on record within the study area. This is probably due to the poor yield and quality of water as described above. In addition other public sources of water are available in the study area. Major industrial users of water (Todd Shipyards, Bethlehem Steel and the Port of Seattle) presently use commercial water sources. No records of any currently operating wells in the study area were found. Williams [23] identified the lower Duwamish River basin as being a low potential area for future water supply development.

The studies have estimated rates of groundwater movement within the shallow aquifer. Estimates of 0.45 to 1.0 feet per day [19] and 0.25 to 2.5 feet per day [20] have been reported. Very limited data is available about groundwater flow rates. It is expected that there are zones or areas of preferential flow that have the capacity to transmit groundwater at rates greater than those reported. The most obvious preferential flow zones would be backfill around buried utilities and foundations and through fill placed in the original Duwamish River channel. No investigations were found which attempt to characterize these flow zones or identify where they might be present.

Very little information is available regarding the effect of the salt wedge in the Duwamish River upon groundwater quality. Sweet,Edwards and Associates [11] imply that brackish water conditions do exist in some areas of the Duwamish River valley. The presence of a groundwater chemistry gradient within the aquifer would affect the behavior of chemical constitutents dissolved in the groundwater. Certain elemental constituents tend to precipitate out with increases in salinity.[11] In areas where saline water intrusion into the groundwater aquifer is minimal, this precipation reaction may occur largely within the sediment zone as groundwater enters the Duwamish River.

Table 4-7 includes an inventory of wells and investigations for which groundwater monitoring wells were installed. The locations for wells and investigations shown on Table 4-7 are illustrated on Figure 4-3. Those wells for which groundwater quality data is available are discussed below.

TABLE 4-7. INVENTORY OF GROUNDWATER WELLS AND INVESTIGATIONS (See Figure 4-3)

| Well Location | Description | Reference |
|---|---|---|
| A | Bethlehem Steel (water supply well) | (22) |
| B | Elliott Bay Mill Co. | (22) |
| C | San Juan Fish Packing Co. | (22) |
| D | Arden Farms | (22) |
| E | RETS* Monitoring Well (DM530) | (13) |
| F | RETS* Monitoring Well (DM545) | (13) |
| G | RETS* Monitoring Well (DM555) | (13) |
| H | Bethlehem Steel (four monitoring wells) | (24), (25) |
| I | Port of Seattle, Terminal 105 | (20), (26) |
| J | SEAFAB Metal Corporation (four monitoring wells) | (29) |

* Renton Effluent Transfer Station

The Renton Effluent Transfer System monitoring wells located within the study area were sampled and the groundwater was tested using a progressive approach. Well DM555 (location G) indicated the presence of chemical residues including volatiles, base, and acid neutral compounds, and pesticides. This well is in the location of the abandoned West Seattle Landfill. Selected results from this well are shown on Table 4-3. Well installation methods and sampling protocol are not well documented. However, the results of the groundwater samples along the proposed RETS alignment indicated that cadmium, chromium, nickel, mercury, silver and selenium were all below detection limits. Zinc and iron were present in all water samples. Six of eleven groundwater samples indicated cyanide levels ranging from 0.005 to 0.028 mg/l.[13]

Four wells located at the Bethlehem Steel Corporation waste pile facility were installed during November of 1981. Laboratory analyses have been conducted for lead and cadmium in the groundwater based upon past EP toxicity testing of slag in the waste pile. Groundwater monitoring results from 1982 to 1984 indicate lead and cadmium levels in groundwater beneath the facility at below the National Interim Primary Drinking Water Standards of 0.01 mg/l for cadmium and 0.05 mg/l for lead.[25]

Three groundwater monitoring wells at Terminal 105 were installed near the perimeter of a landfill used for disposal of about 16,000 cubic yards of contaminated dredge spoils. The landfill was constructed and filled during January, 1982 by the Port of Seattle. Some of the dredge material was contaminated with PCB ranging from 2 to 4 ppm. In order to evaluate the impacts of this disposal on the groundwater, samples were obtained from the wells prior to disposal and at intervals of one, two, four, seven and twelve months after disposal. Sampling intervals were selected based upon well locations, permeability of surrounding soil and the expected dewatering of dredge spoils after placement. The parameters determined for the water samples were pH, salinity, TOC, sulfide, total suspended solids, and priority pollutants. The results indicated that PCB was not present in the groundwater samples. Detectable levels of inorganics and organics were in extremely low concentrations. Overall, the results indicated that the disposal of contaminated dredge material had minimal effects on the groundwater down-gradient from the landfill.[26]

Four groundwater monitoring wells were installed at the SEAFAB (formerly Quemetco) secondary lead facility on Harbor Island as part of the closure of a waste impoundment located in the southeast corner of the facility. Although no data from these wells were available during Phase I, a sample taken from an additional older well on the west side of the SEAFAB facility (identified as MW-1 in the closure plan) showed lead present at a concentration of 0.01 mg/l and cadmium of 0.02 mg/l.[28]

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## 5.0 SURFACE WATER INVESTIGATION

### 5.1 MARINE AND ESTUARINE PHYSICAL DESCRIPTION

#### 5.1.1 Introduction

The study area is located in the lower reach of the Duwamish estuary, which has been dredged extensively to permit navigation of commercial vessels. The dredging and channelization have significant impacts on circulation, transport, and sedimentation within the study area. Water depths in the study area are shown in Table 5-1.

TABLE 5-1. APPROXIMATE MID-CHANNEL WATER DEPTHS IN THE STUDY AREA

| | | |
|---|---|---|
| West Waterway | 50 ft MLLW | 15 m MLLW |
| East Waterway, North End | 50 | 15 |
| East Waterway, South End | 40 | 12 |
| Harbor Island Reach | 25 | 7.6 |
| Duwamish Waterway near Kellogg Isl. | 20 | 6.1 |
| East Channel (non-navigable) | 10-20 | 3.0-6.1 |

Source: National Ocean Survey Chart No. 18450

The Duwamish River has an average annual fresh water discharge of 1514 cfs (42.9 cms) measured at mile 12.4 (20.0 km) near Tukwila, Washington.[1] The extremes observed over the period of record are the high discharge rate of 12,100 cfs (343 cms) and a low of 195 cfs (5.5 cms). Typical peak discharge rates occur in December through February due to high precipitation with a secondary peak in May or June due to snowmelt.

Puget Sound tides are of the mixed type, having two unequal highs and lows each tidal day of 24.8 hours. These tides can be computed accurately for any location and are published annually by the National Ocean Service.[2] However, astronomical tides do not account for the effects of variable meteorological forces or the stage of the Duwamish River. The difference between actual and predicted tide height may be up to 3 feet due to strong winds, low barometric pressure, and/or high river discharge. Astronomical and actual tide data for Elliott Bay are shown in Table 5-2. Annually, the highest tides occur in December or January and the lowest in June or July.

TABLE 5-2. TIDE DATA FOR ELLIOTT BAY

| | | |
|---|---|---|
| **Astronomical Tides**[3] | | |
| Mean Higher High Water | 11.3 ft | 3.4 m |
| Mean High Water | 10.5 | 3.2 |
| Mean Sea Level | 6.6 | 2.0 |
| Mean Low Water | 2.8 | 0.9 |
| Mean Lower Low Water (MLLW) | 0.0 | 0.0 |
| **Historical Tides** | | |
| Highest Recorded Tide[4] | 15.2 ft | 4.6 m |
| Extreme Low Water[3] | -4.5 | -1.4 |

### 5.1.2 Salt Wedge Dynamics

The lower reach of the Duwamish estuary is regarded as a highly stratified or salt wedge estuary. The estuary is characterized by a layer or wedge of undiluted seawater of fairly uniform salinity beneath a seaward-flowing layer of combined freshwater and seawater. Net flow, driven by density gradients, is upstream in the salt wedge. The maximum upstream excursion of the wedge toe extends past the East Marginal Way Bridge (mile 7.8) during low summer river discharge.[5,6] The toe of the salt wedge is always at least as far upstream as the 16th Avenue South Bridge. Measurements at the 16th Avenue South Bridge indicate that the Duwamish estuary lies between the type 4 and type 2b categories of the Hansen/Rattray classification system.[7,8]

The Duwamish estuary is characterized by a zone of turbulent mixing between the salt wedge and the mixed surface layer. Salt water advected upstream in the wedge is entrained into the surface layer and advected seaward. The depth of the interface in the study area, defined by the 25 ppt isosal, typically varies between 3 and 13 feet of depth (1 to 4 meters) depending on the tide and river stages.[5,9] Fluorescent dye studies have shown that there is little or no downward movement of water from the upper layer into the salt wedge.[10] Field studies near the 16th Avenue South Bridge indicate that the velocity of upward entrainment of salt water ranges from $30(10)^{-6}$ to $100\ (10)^{-6}$ cfs/sq. ft., with a net upstream flow of 135 to 260 cfs in the salt wedge.[11] An equation relating entrainment velocity to river discharge rate and tidal prism thickness predicts similar results.[5]

### 5.1.3 Local Circulation Patterns

In general, the salt wedge dynamics and resultant net flow of the Duwamish estuary are well documented in studies conducted by the United States Geological Survey.[5,6,10,11,12,13] However, ocsillatory tidal circulation and wind-generated currents have received little attention. The data of Longfield[12] indicate that stratification effects on currents (i.e., salt wedge dynamics) decrease toward the seaward end of the estuary. Therefore, winds and tides presumably have significant control over local current patterns within the study area. Transport and deposition of pollutants and particulates within the study area is determined by these high frequency current variations as well as the net estuarine flow. Water entering the upper layer may experience some tidal ocsillation (depending on tide and river stage), but would ultimately be advected into Elliott Bay with water entrained from the salt wedge. Water entering the salt wedge either returns to the sea on the falling tide or remains in the wedge and moves upstream until it is entrained into the upper layer and is returned to the sea.

Local tidal circulation patterns within the study area have been examined in hydraulic models at the University of Washington's Harris Hydraulics Laboratory.[14,15] Both studies examined the change in flushing characteristics by proposed development in the East Waterway. The results are expressed in qualitative terms of comparative flushing rates between the alternatives, thus are of limited value in describing existing circulation. These and other studies have documented that flushing efficiency in the East, West, and Duwamish Waterways is a function of the river discharge and tides. Flow measurements indicate that about 80 percent of the river flow passes through the West Waterway due to channelization. Existing information is not adequate to determine site- specific circulation patterns, such as the pathline of pollutants from a given source or the interaction of currents with piers and abutments.

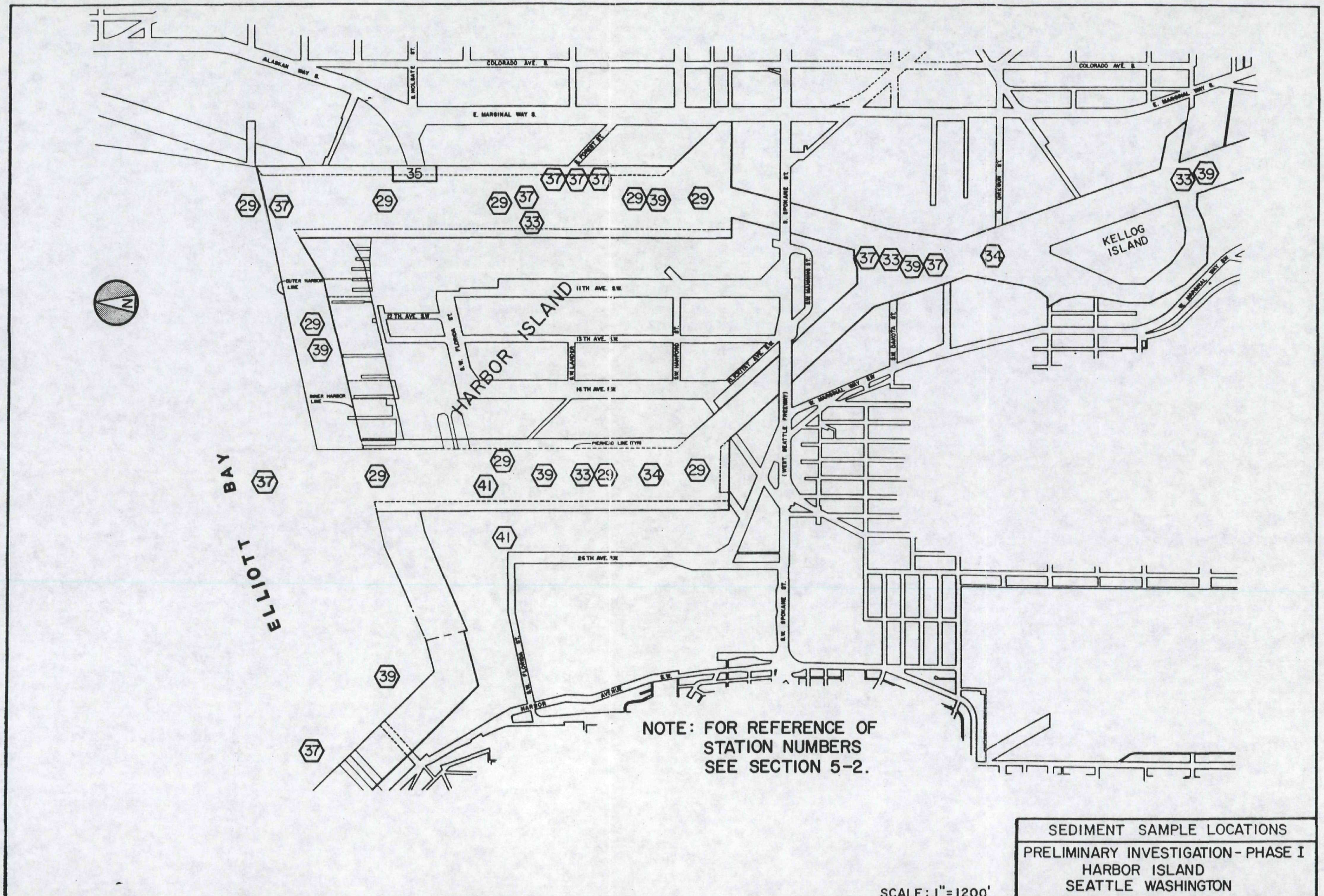
### 5.1.4 Sediment Transport and Deposition

Sediments in a river are transported downstream as either suspended load or bed load, and may deposit at some location where the river bed slope decreases and the channel widens. Edmondson[16] conducted the most comprehensive study of sediment transport and deposition within the Duwamish estuary. He developed curves relating average monthly river flow to the net sediment accumulation rate for several subregions in the estuary, including the study area. Generally, deposition occurs during the low and average flows with local scour, and resuspension occurs during the high flows, although there is a net deposition in all areas. The rate of deposition is also strongly related to the geometry of the basin. Channelization and dredging have created a stair-step geometry of increasing depth seaward. Deposition tends to be enhanced at the upstream ends of the individual basins and where flow has been diverted.[17]

Data collected by Edmondson[16] indicate highly variable deposition rates in the study area. The deposition rate in the East Waterway is higher than in the West, primarily due to the diversion of most flows to the West Waterway with associated higher current velocities. At high river discharge, sediment that enters the West Waterway as suspended load passes through it and out to Elliott Bay. Further examination of dredging records would be necessary to determine more site specific deposition rates within the study area.[18] Surficial characteristics of the most seaward portion of the study area is probably influenced strongly by wave action, but has not been examined. Site specific, near-bottom current measurements would be necessary to determine the potential for re-entrainment of sediments at any location of interest and the probable paths of such particles.

## 5.2 MARINE/ESTUARY WATER QUALITY

Normally water quality in the lower Duwamish Estuary may be said to be largely governed by the quality of marine waters of Puget Sound. However, waters of the lower Duwamish are impacted by activities occuring within the study area (see Figure 5.1) and also by upstream inputs of wastewater, runoff, and other pollutant discharges. The Renton wastewater treatment




SEDIMENT SAMPLE LOCATIONS

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE WASHINGTON

FIGURE 5-1

plant discharges secondary effluent to the river at river mile 12.8 and has been noted to contribute approximately 80 percent of the total ammonia load to the downstream reach[19]. A recent summary of pollutant loadings to the lower Duwamish has been compiled by Harper-Owes[19] (1983) for various sources that discharge to the river (see Table 1, Appendix A). Other additional pollutant sources include storm drains, combined sewage overflows (CSOs), industrial discharges (direct and indirect), atmospheric inputs, and deep advection from Elliott Bay.

Although pollutant loadings to the Duwamish may at times be high, river discharge and tidal mixing and flushing processes described in Section 5.1 can act to reduce the water column concentrations of many of these pollutants in the study area. Exceptions to this were noted in the Harper-Owes[19] study, which indicated that water column concentrations of cadmium, copper, lead, and mercury in the lower Duwamish exceeded the USEPA water quality criteria for chronic and in some cases acute levels of these metals on a nearly year-round basis. Data from the Harper-Owes[19] report presented in Table 5.3 show the chronic and acute concentrations (where developed) of Cd, Cu, Pb, and Hg for the protection of marine aquatic life (at river km 2). From the table it can be seen that cadmium was observed to exceed the chronic and acute criteria concentration at km 13. However, since a primary point source of cadmium was noted to be the Renton WTP (90 kg per year), dilution in the lower estuary and presumably in the study area (i.e., km 0-2.5) might be expected to reduce the concentration to below the criteria limit. Concentrations of other metals (i.e., arsenic, nickel, and zinc) were said not to reach levels shown to be potentially harmful to aquatic life in the lower Duwamish Estuary. It should be noted that background alluvial sediments in the Duwamish system show relatively high concentrations of Hg (Mean 1970-1980 concentration of 0.55 mg/kg). Natural upstream inputs are said to account for this.[19]

Polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and heavy metals have been shown to be present in suspended matter recovered from the water column in the lower Duwamish study area.[20,22] (See Tables 2-6, Appendix A).

Polychlorinated biphenyls (PCBs) in the Elliott Bay-Duwamish River system have been shown to be distributed in distinct horizontal and vertical gradients corresponding to the distribution of the more contaminated saline layer of river water.[22] PCB concentrations in the water column were shown by Pavlou and Dexter[22] to decrease linearly with increasing salinity. They reported water column concentrations of PCBs in the lower Duwamish of 22 $\pm$13 ng/L and in the surface film 116 $\pm$101 ng/L. Pavlou and Dexter[22] presented data showing that under equilibrium conditions the PCB concentration in sediments subjected to a somewhat uniform input does not vary greatly from the corresponding concentrations found in suspended particulate matter from the overlying water. The authors applied the equilibrium partitioning concept to a general ecosystem distribution of PCB's in the Duwamish/Elliott Bay sustem. Conclusions were based upon spatial and temporal trends in PCB concentrations observed in Puget Sound and the Duwamish Estuary between 1973 and 1977 and an evaluation of partitioning mechanisms in suspended matter phases and in lower trophic level biota. Spatial patterns were said to agree well with prevailing circulation as mapped by sediment biotype studies. Therefore, PCB concentrations in water and other ecosystem components can be inferred from levels observed in adjacent sediments and thus, sediment sampling can be said to be a preferred method for detection of such contamination and evolution of potential impacts.

Other water column sampling in the study area has been conducted or summarized by other workers[9,11,17,23,24,25,26,27,28,29,30,31] but according to Harper-Owes[19] a limited data base exists with respect to organics present in the water column and for this reason it was concluded that examination of water column, impacts would probably not be the best approach for determining organic pollutant loads.

Therefore, it appears that an analysis of sediment pollutant characteristics in the lower estuary will provide a more meaningful assessment of water quality, potential impacts, and sources of pollutants.

TABLE 5.3 LOCATION AND TIMING OF DUWAMISH WATER COLUMN METAL CONCENTRATIONS THAT PRESENTLY (1976-1981) EXCEED EPA AQUATIC LIFE CRITERIA.[a] (ug/L).

| Metal | Location (Timing) | Chronic Criteria | Level Observed | Acute Criteria | Level Observed |
|---|---|---|---|---|---|
| Cadimum | Km 29 (Annual) | 0.007 | 0.13 | 0.82 | 1.4 |
| | Km 13 (Annual) | 0.007 | 0.31[b] | 0.88 | 1.5 |
| | Km 13 (Low Flow) | 0.010 | 0.49[c] | 1.2 | 1.7 |
| Copper | Km 2 (April-June) | 4.0 | 19.[d] | 23. | 36. |
| | Km 2 (Summer/Fall) | 4.0 | 22.[d] | 23. | 42. |
| | Salt Wedge (Annual) | 4.0 | 18. | 23. | ca. 100. |
| Lead | Km 29 (Annual) | 0.21 | 2.0 | --- | --- |
| | Km 13 (Annual) | 0.24 | 3.5[b] | --- | --- |
| | Km 2 (April-June) | 25. | 84.[d] | --- | --- |
| | Km 2 (Summer/Fall) | 25. | 96.[d] | --- | --- |
| Mercury | Salt Wedge (Annual) | 0.1 | 0.28 | --- | --- |

[a]Table from Harper-Owes (1983).[19]

[b]Annual mean concentration; observed values refer to predicted total recoverable concentration.

[c]Renton WTP is a major cadmium (esp. dissolved Cd) source to the upper Duwamish during summer low flow.

[d]Seasonal maximum concentration based on concentration/flow regression and average annual low flow during that season.

The most recent (1985) compilation and summary of water quality data collected in the study area was prepared by Tetra Tech for the USEPA.[32] That report also cited the transient nature of water column data and the difficulty of data interpretation for spatial and temporal studies in a system like the Duwamish. The lack of intensive water column sampling for the Elliott Bay/Duwamish River system was also noted. In addition, sediments were said to provide a more effective sampling matrix for pollutant source and impact interpretation than water column data.

## 5.3 MARINE/ESTUARY SEDIMENT CHEMISTRY

The deposition rate of sediments in the East and West Waterways of the study area has been estimated by Edmonson[16] based on average monthly river flows. Most deposited sediments in the lower estuary are found in several large shoals, and during periods of low river flow the East and West Waterways, they act as settling basins for particulate matter. Owing in part to this and to the heavy load of various pollutants discharged to the estuary, sediments to the lower reaches of the Duwamish have reportedly been shown to have the highest concentrations of lead, zinc, and mercury and the second highest concentration of copper in Puget Sound.[33]

Dexter and co-workers[33] have summarized various published and unpublished studies of selected heavy metals (Cu, Pb, Zu, and Hg) observed in sediments of the lower Duwamish and Elliott Bay (see Figures 1 and 2, Appendix A). These workers implicated the Diagonal Way and Hanford Street CSO (East Waterway) and other smaller CSOs and stormdrains in the lower river with producing local sediment impacts for elevated concentrations of Cu, Pb, and Zn. Pb was also identified in storm drains of western Harbor Island and was said to arise from activities of a secondary lead smelter located on Harbor Island. The Harbor Island shipyards and dry docks were also reported to be the source of a major input of Cu. Heavy metal distributions in the lower waterway were said to imply (1) limited movement and transport from the sources, (2) rapid dilution of the mobile fraction over a short distance to near background levels and, (3) a patchy accumulation pattern in sediments.

Recently (March 26, 1984) the U.S. Army Corps of Engineers dredged river sediments (1100 cubic yards) from a small shoal area located just north of Kellogg Island[34] (see Figure 5-1). Channel depth in the shoaling area had been restricted to a depth of approximately 25 feet at mean lower low water thus considerably limiting shipping draft at this point in the channel. Therefore, dredging and removal of this shoal was undertaken. Shoal sediment concentrations of Cu, Pb, Zn, As, Cr and organics (Aldrin) were in excess of allowable EPA criteria to permit open-water disposal in Elliott Bay (see Table 7, Appendix A). PCB's (1.4-3.1 ppm) were also shown to be present in shoal sediments. These contaminated sediments were disposed of in the upper West Waterway and capped with clean sediments obtained from river mile 6.2.

The Harper-Owes[19] study for METRO (1983) has summarized sediment data collected in the Duwamish estuary by various researchers. The report presents longitudinal (river km 0-10) variation in sediment concentrations of As, Cd, Cu, Hg, Pb, Zn, total polychlorinated biphenyls (PCB), and total polyaromatic hydrocarbons (PAH) for various periods during 1972-1982. Also discussed were the loadings of those and other contaminants and their possible sources. A major finding of the study was that loadings of metals and organics cannot be ascribed to documented sources. Inputs of such contaminants may be infrequent and include transient sources such as ships that may discharge pollutants overboard while passing up or down the estuary.[33]

As part of the Port of Seattle's Terminal 30 expansion project, sediment chemistry analyses have recently (1984) been completed on sediments collected from the East Waterway and the area of Terminal 30.[35] High concentrations of heavy metals and organic pollutants were identified at various locations and depths. Sediment sample stations are noted in Figure 5-1. Additional sediment chemistry data has been reported by various workers for samples collected in and near the study area. These studies have discussed dredging impacts,[23,27,31] the relationship of sediment contaminants to aquatic biota,[36,38,39] and the distribution of various contaminants in sediments of the Duwamish and other areas of Puget Sound.[21,37,39]

Dredging activities in Elliott Bay and the lower Duwamish reportedly release small amounts of refractory chemicals (e.g., TOC, PCB's, and oil and grease) to the water column.[27] Other studies have indicated that Duwamish dredging has a minimal effect on salt wedge dissolved oxygen,[23] ammonia or other toxin release.[23,43] Other studies have indicated that turbidity increases are expected in the Duwamish due to the nature of dredge spoils but that nutrients or heavy metal concentrations should not exceed 2 to 4 times ambient concentrations.[31]

The relationship of sediment contaminants to aquatic biota have also been studied in the area of the lower Duwamish. Studies by Malins and co-workers[36,38,39] have indicated that the chemical composition of the sediment is generally reflected in tissues of subarea organisms. Biotic studies conducted in the lower Duwamish area are discusseed in Section 7.0

The spatial distribution of various sediment contaminants in the lower Duwamish and other areas of Puget Sound have been documented by several workers.[21,37,39] High Hg concentrations (0.5 ppm) have been noted at the mouth of the estuary by Crecelius and co-workers[21] while Malins, et al.[39] demonstrated not only high concentrtions of Hg (up to 1.4 ppm) but other heavy metals as well (see Figure 4, Appendix A). METRO's 1984 Toxicant Pretreatment Planning Report[37] has identified sediments in the Harbor Island area as a Central Puget Sound Basin "hotspot." Contaminated sediments in the East and West Waterways showed the following toxicant concentration ranges:

AS, 3-24 ppm;
Cd, 0.8 - 1.6 ppm and greater;
Cr, 20 - 80 ppm;
Cu, 60-120 ppm and greater;
Pb, greater than 150 ppm;
Hg, 0.4 - 0.8 ppm;
Zn, 100-400 ppm;
Total DDT, 16-32 ppb;
Low molecular weight PAH's, 1000 - 4000 ppb and greater;
high molecular weight PHA's, 6000 - 24,000 ppb and greater;
and Total PCM, 150 - 750 ppb and greater.

Sediment sampling locations are noted in Figure 5.1.

Sediment data collected in the Duwamish at storm drain outfalls arising from Harbor Island were summarized in the 1983 RAMP[40] report and indicated that high concentrations of lead and copper could be attributed to various storm drains. Specifically, the highest Pb values were noted from the SW

Lander Street drain and the highest Cu concentrations were found near the SW Florida Street drain.

Reflecting these and the earlier findings of Dexter and co-workers,[33] the storm drain at SW Lander Street (West Waterway) was recently cleaned of Pb contaminated sediments. Also, the storm drain located at SW Florida Street recently (1985) has been shown to contain sediments contaminated with various metals and organics.[41]

The most recent summary of sediment data in the study area was completed in 1985 by Tetra Tech.[32] That summary analysis of data collected in and around Elliott Bay and the lower Duwamish included sediment chemistry information collected between 1979 and 1983. The Tetra Tech[32] report noted that sediment sampling in the area of north Harbor Island has not been intensive enough to determine whether or not elevated mean values represent localized hot spots or more widespread contamination. High concentrations of PCBs were reportedly observed near the mouth of the East Waterway while elevated metals were noted at the mouth of the West Waterway. Further data summary by Tetra Tech of sediment sampling in the East and West Waterways concluded that high levels of Cu, Pb, and Zn were observed near CSOs on the east side of the East Waterway, and that East Waterway sampling intensity is sufficient to rank it with more contaminated areas in Puget Sound. Relatively high concentrations of arsenic and PCBs have been observed in sediments located near the west bank of the West Waterway at the mouth. High concentrations of metals were noted near the SW Lander Street storm drain, and PAHs, while showing no spatial trends, were found to be high in the West Waterway. Elevated mean values for most chemical species were said to decrease upriver of the Harbor Island area, thus reflecting a decrease in the number and volume of sources; however, nearly all boat slips along the river were said to exhibit contaminated sediments. Finally, it was noted that available sediment data for the West Waterway is too sparse to identify the extent of gross contamination present.

From the sediment chemistry data collected in the past and the various summaries and analyses of the available data, it can be demonstrated that sediment contamination by heavy metals and various organics is generally a localized occurrence in the lower Duwamish Estuary. Discharges of various pollutants may be traced, in many cases, based on sediment characteristics in the surrounding area. Thus, cleanup and elimination of pollutant sources within the study area may be expected to be based upon the continued documentation of contaminated sediments located in close proximity to discharge sources.

Various reports have either directly or indirectly implicated industrial sources as the major contributors of organic and inorganic pollutants in the lower estuary.[19,33,40,41,42] Leaching of contaminated material from older fill areas in the lower Duwamish has also been suggested as a source of pollutants.[42] These fill areas identified and mapped (see Figure 3, Appendix A) by Harper-Owes[42] are in many cases located adjacent to the Duwamish and some have historically been utilized as waste disposal sites. Leaching of wastes from groundwater conduits through unconsolidated fill material may contribute to pollutant loading in the Duwamish.

From the data it can be said that many suspected and known outfalls that discharge contaminants to the estuary have been identified. For those documented outfalls it appears that identification of the source(s) and implementation of appropriate abatement programs must now be considered. There remain areas within the study reach that require further investigation. These include: examination of sediments located in blind slips, further investigative sampling to ascertain additional sources of contamination, and sampling of Duwamish sediments and water near old fill sites in order to determine the magnitude of water and sediment impacts arising from historical waste disposal at these sites. Identification of pollutant contributions from the contaminated fill sites may justify remedial measures at such sites.

Overall, the cleanup or removal of identified and yet to be identified hot-spots may or may not prove to be practicable. In any case, identification and elimination of remaining pollutant sources would appear to be the most efficacious method of curtailing ongoing contamination of Duwamish water and sediments. After this has been accomplished, the removal and disposal of contaminated sediments may then be realistically addressed.

## 5.4 DRAINAGE

The entire study area is served by both sanitary sewers and storm drains. Generally, the sanitary sewers collect industrial and sanitary wastewater, while storm drains collect surface runoff.

### 5.4.1. Sanitary Sewers

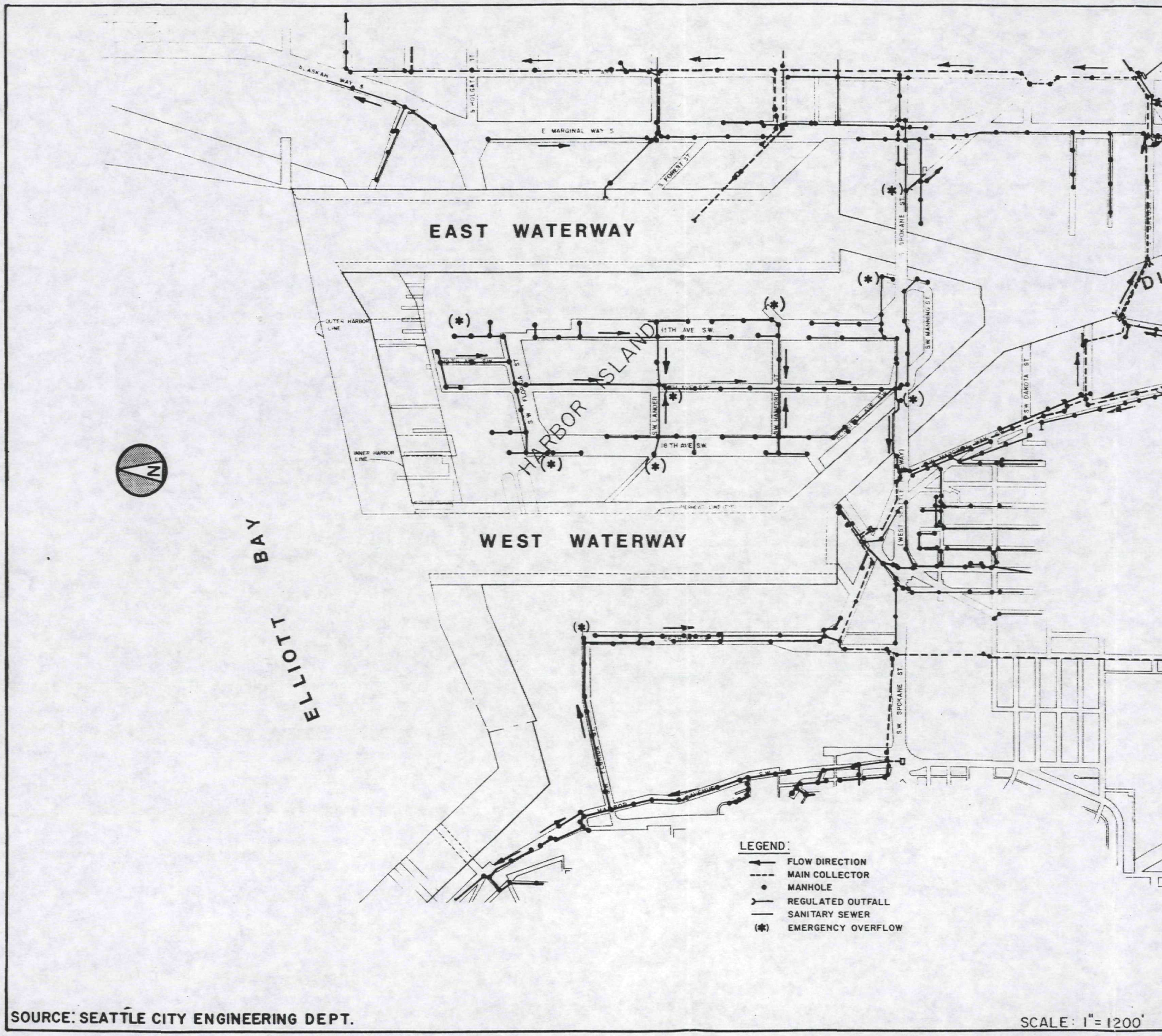
Wastewater from Harbor Island is handled by the City of Seattle Sanitary sewerage system. This flow is consolidated at the sound end of 13th Avenue SW, then pumped across the West Waterway into the METRO system as shown on Figure 5-2.

There are two sewerage lift stations on Harbor Island; one is lcoated at the intersection of SW Lander Street and 13th Avenue SW and Klickitat Avenue.[44] There are no combined sewer overflows in the island;[45] however, there are six emergency overflows that could discharge into the drainage system in order to prevent backups. It is reported that these emergency overflows operate at a frequency of not more than twice every decade.[45]

The Harbor Island sewer lines belonging to the City of Seattle vary in size from 8 to 24 inches. There are no sewer force mains in Harbor Island except for the 12-inch line that carries the flows across the West Waterway and into the METRO main collector on West Marginal Way SW.

Sewage generated in the east portions of the study area (east of the East Waterway) flow into the METRO collector located and flowing to the north on Colorado Avenue S. This sewer passes through a tunnel under downtown Seattle and is discharged at the West Point Treatment Plant.[44,46] A number of regulator gate structures are located on East Marginal Way S.

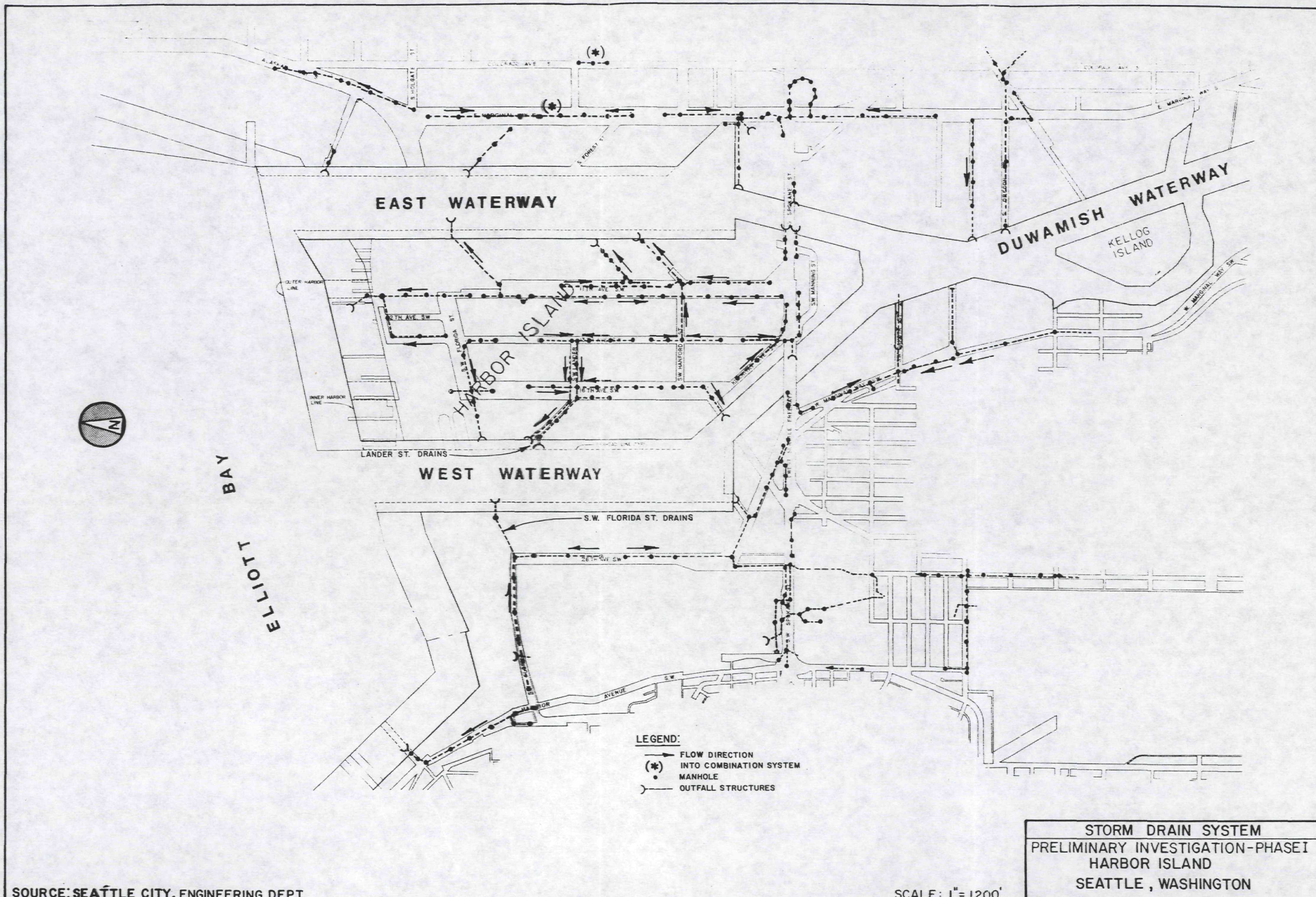
The wastewater discharge from the west portion of the study area is transported via the METRO collector on West Marginal Way S. This flow is siphoned across the Duwamich river and then into the Colorado Avenue South sewer system flowing to the West Point Treatment Plan.




SANITARY SEWER SYSTEM

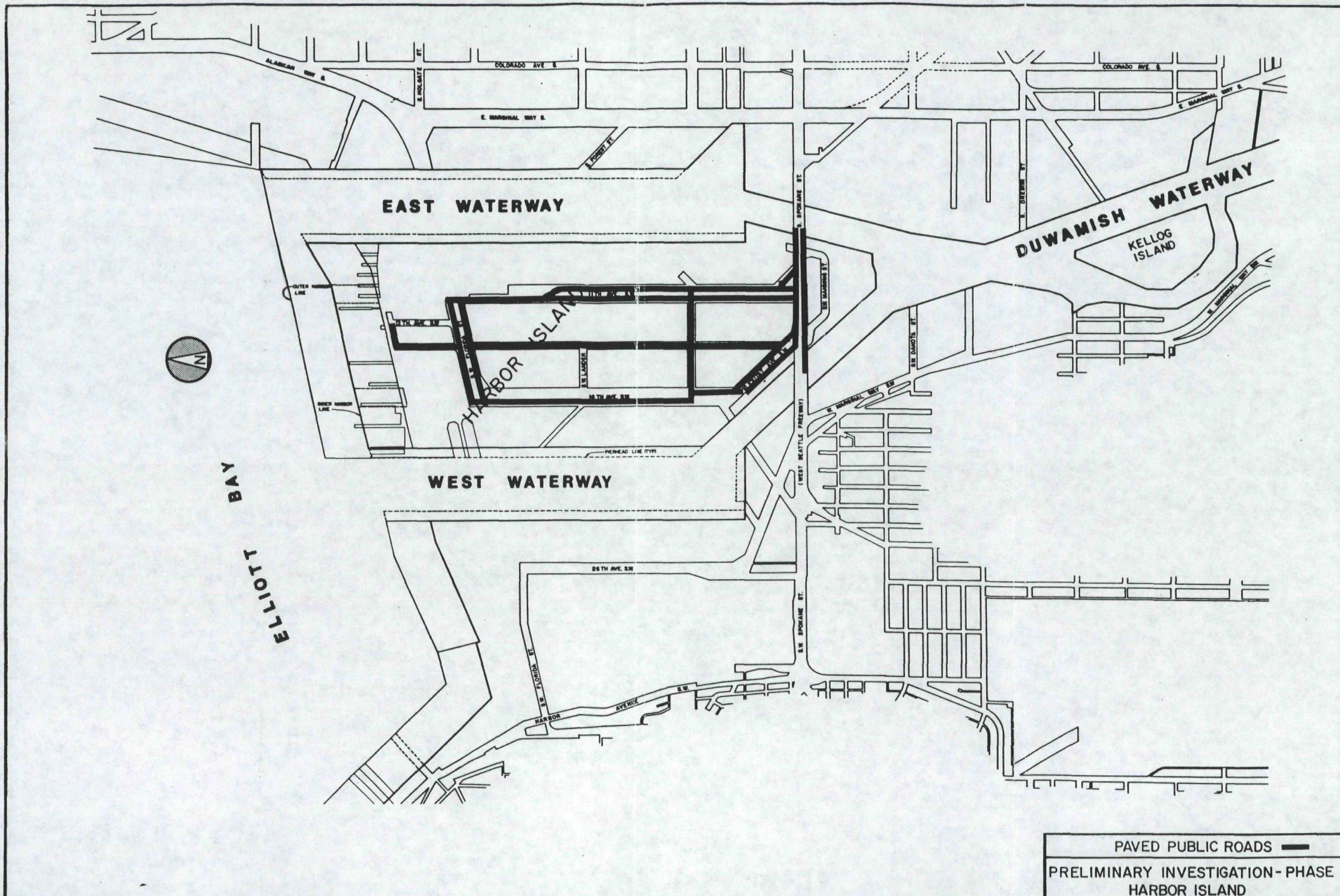
PRELIMINARY INVESTIGATION-PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

FIGURE 5-2




STORM DRAIN SYSTEM
PRELIMINARY INVESTIGATION-PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

FIGURE 5-3




SOURCE: CITY OF SEATTLE, MAINTENANCE DEPT.

SCALE: 1" = 1200'

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

FIGURE 5-4

5.4.2 Storm Drains

Surface runoff is collected and drained from the site via a storm drain system made of catch basins, drainage manholes, and a complex of drainage pipes. This system discharges at eleven outfalls around the perimeter of the Harbor Island and into the East and West Waterways as shown on Figure 5-3. The majority of Harbor Island has been paved; this include roads (see Figure 5-4), parking lots, and the Port of Seattle Terminal 18 facilities. Terminal 18 occupies approximately 20 percent of Harbor Island. There are no natural ponds on Harbor Island. The only natural water accumulation that takes place on the surface of the island is small puddles along road sides, rail lines, and parking areas.

The surface water drainage system for the study area is owned and maintained by the City of Seattle. Some facilities near the perimeter of the waterways have private drain lines that discharge directly; permits are issued for these on an individual basis by the City.[46] The discharge point of the drain lines is designed such that the hydraulic grade line is maintained below required level in order to prevent backup pressure, from the waterway tide fluctuation.[44]

Surface drainage generated in the east portions of the study are (east of the East Waterway) is collected by a system of drains discharging into main lines located on the Alaskan Way S. Part of this system discharges into the East Waterway at S. Massachusetts Street, Stacy Street, and at Hinds Street. However, the area between S. Holgate Street and S. Forest Street discharges into the sanitary sewer system at the west end of S. Lander Street as shown on Figure 5-2.

Runoff on the west portion of the study area (east of the West Waterway) is gathered in drain lines along SW Florida Street, 26th Avenue SW, and West Marginal Way SW. Outfall structures are located on SW Florida Street, SW Hinds Street, and on SW Spokane Street; and a discharge ditch is located at the east end of SW Dakota Street.

## 5.5 SUMMARY

The marine/estuary hydraulics of the lower Duwamish River (including the Harbor Island study area) are complex due to the effects of channelization, astronomical and meterological tides, winds, salt wedge stratification, and seasonal river flow variations. This complexity limits the usefulness of water (column) quality data for identification of pollution sources because it is not possible to document toxicants present in a water sample entered the water at the sample point or from some other location. The usefulness of sediment data also is limited by the complex hydraulics, although to a much lesser extent. Therefore, data regarding sediment quality in the study area are of primary importance for identifying pollutant sources.

Several studies have been conducted in the Harbor Island study area to determine the levels of toxicants in sediment and the water column. Existing data indicate water column concentrations of various heavy metals in the area exceed EPA criteria for aquatic life. Sediment data also show elevated levels of heavy metals and organic toxicants at the Harbor Island site. In most cases, uncertainties regarding hydraulics and sediment transport mechanisms on a localized scale limit the ability to conclude that these toxicants are the result of sources within the Harbor Island area.

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# 6.0 AIR INVESTIGATION

## 6.1 AIR MONITORING ACTIVITIES

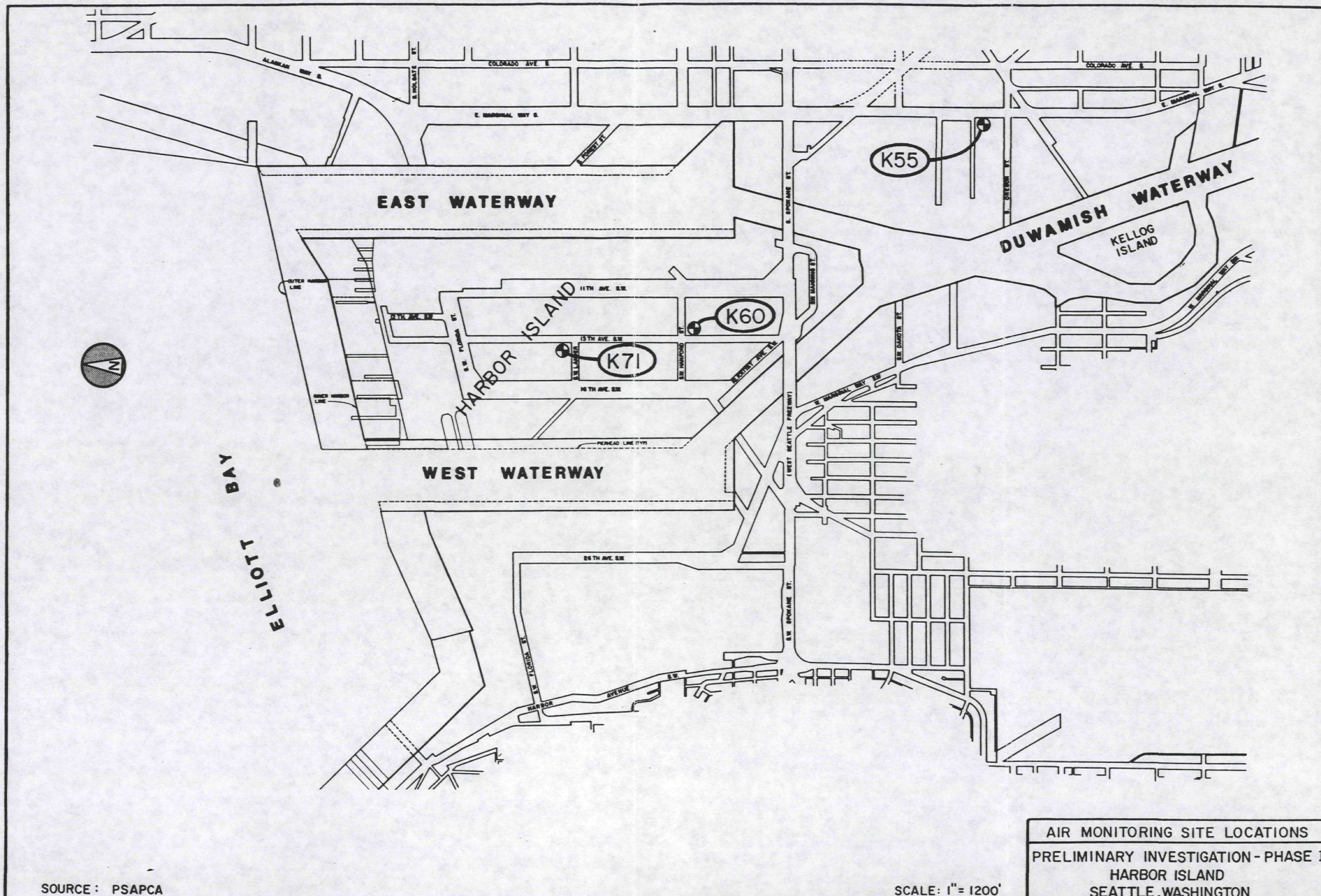
The Puget Sound Air Pollution Control Agency (PSAPCA) has monitored the air quality in the Puget Sound Region since 1967. The PSAPCA sampling network extends throughout the area and is more concentrated in locations with polluting sources. Three air monitoring sites operated by PSAPCA are within the study area. The air quality evaluation within the study area is based on these monitoring sites and on the various references and air models that address the lead and total suspended particulate (TSP) air concentrations in the study area.

The three PSAPCA air monitoring sites are described and located as follows (Figure 6-1):

| | |
|---|---|
| K55 | 4401 E. Marginal Way S. |
| K60 | 3400 13th Ave. S.W.<br>Harbor Island |
| K71 | 2555 13th Ave. S.W.<br>Harbor Island<br>(300 feet north of lead smelter, on top of Texaco Distribution Center) |

The two stations on Harbor Island, Air Monitor Sites K71 and K60, are equipped with high volume samples for monitoring TSP and lead levels. Air Monitor Site K55, the Duwamish site, currently monitors TSP, fine particulates, wind speed, wind direction, and sulfur dioxide levels.

Historically, lead and TSP ambient air concentrations have been high in the Harbor Island area. The local lead problem resulted primarily from the operations of a secondary lead smelter on Harbor Island. The high suspended particulates in the area are a result of the varied industrial activity, automobile and heavy truck traffic, construction activity, and fuel combustion.[1]




AIR MONITORING SITE LOCATIONS

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

FIGURE 6-1

## 6.2 LEAD EMISSIONS

The Monitoring Site K71, located nearest to the secondary lead smelter, has been in operation since January 1981. Until 1984 this location had consistently been a non-attainment area based upon the national ambient air lead quality standard of 1.5 ug/m$^3$ averaged over one calendar quarter. Table 6-1 outlines the available air lead data for the years in which Harbor Island has been monitored by PSAPCA.

TABLE 6-1. HARBOR ISLAND AMBIENT LEAD CONCENTRATION SUMMARY (ug/m$^3$)

| PSAPCA Station No. | Location | Year | Quarterly Measurement First | Second | Third | Fourth |
|---|---|---|---|---|---|---|
| K60 | 3400 13th Ave. SW | 1977 | | | | 2.34* |
| | | 1978 | 2.13 | 1.61* | 1.51 | 2.33 |
| | | 1979 | 2.02 | 2.26 | 2.10 | 1.50 |
| | | 1980 | 1.26 | 1.00 | 1.27 | 1.02 |
| | | 1981 | 1.16 | 0.39 | 0.76 | 0.68 |
| | | 1982 | 0.89 | 0.86 | 1.05 | 0.68 |
| | | 1983 | 0.47 | 0.54 | 0.67 | 0.65 |
| | | 1984 | 0.63 | 0.23 | 0.38 | 0.65 |
| K71 | 2555 13th Ave. SW | 1980 | | | | 13.20* |
| | | 1981 | 6.90 | 10.55 | 6.85 | 5.33 |
| | | 1982 | 8.41 | 6.97 | 5.24 | 3.88 |
| | | 1983 | 4.17 | 5.18 | 4.78 | 4.56 |
| | | 1984 | 1.57 | 1.48 | 1.03 | 1.06 |

Underlined values represent non-attainment levels.

*Less than three month averages.

SOURCE: References 2 and 3.

Strategies to control the lead levels on Harbor Island have been implemented since 1980 involving several agencies and industries including PSAPCA, the City of Seattle, and the lead smelter. The PSAPCA chemical mass balance receptor model study and industrial source complex model study assessed and quantified the contributions of lead sources to the measured ambient concentrations. These studies concluded that course particulate fugitive emissions and controlled emissions of lead monitored at Monitoring Site K71 were primarily from the lead smelter. They also concluded that fugitive dust from the lead smelter yard accounted for about 50 percent of the total suspended mass lead particulates. The lead smelter's lead pot bag house stack was determined to be the larger contributor of the finer lead particulate. Other sources of lead concentrations were attributed to entrainment of dust from nearby roads and parking areas adjacent to the lead smelter. A smaller percentage, 9.4 percent, was attributed to entrainment of lead from soils north and south of Monitoring Site K71 and to transportation and unsampled activity occuring on and off Harbor Island.[4] Vehicle exhaust was determined to make only minor contributions of 1 percent or less to the fine and total lead fractions monitored in the area.[2]

The Lead Control Plan for the Washington State Air Quality Implementation Plan was first developed by PSAPCA and the Washington Department of Ecology in 1980 and was revised in 1983. The Plan describes strategies to reduce lead emissions in the state to the 1.5 $ug/m^3$ quarterly lead standard attainment level by 1987. The plan involved controls for reducing lead emissions from parking lots and from the lead smelter. Paving of specified lots and areas occurred from 1980 through July, 1983. The smelter also implemented a number of lead emission control actions such as the installation of Gore-Tex Bags in the Reverb Bag House in 1982.[5]

In June of 1984, with a change in ownership of the smelter, there was a change in operations at the facility in which the smelting and refining operations were discontinued.[6]

In January of 1985, the EPA approved a PSAPCA revision to the State Implementation Plan for lead, which recognized the cessation of the lead smelting operations on Harbor Island. The EPA evaluation of these circumstances determined that the lead standard would be attained in the area and that no further control measures for lead would be necessary.[7] The 1984 quarterly averages at Monitoring Site K71 demonstrate an ambient lead concentration reduction when compared to previous years. The 1.5 $ug/m^3$ standard was attained in the final 3 quarters of 1984.

## 6.3 LEAD EXPOSURE

As a result of the lead levels detected by PSAPCA in the ambient air and in the soil, the concern of the public exposure to lead resulted in several blood level studies. Periodic monitoring of workers employed on and in the vicinity of Harbor Island has also been implemented. Prior to the paving projects starting in 1980, three cases of lead exposure to children of workers on Harbor Island were documented.[8] Consequently, a screening of blood samples obtained in an ongoing Woman-Infant-Child SW District Survey for blood hematocrits was implemented by the Department at Social and Health Services and the King County Health Department to include additional screening for blood lead levels. The sample target area included Harbor Island and neighboring communities extending west to California Avenue SW; south to SW Juneau St., east to Fourth Avenue, and north just beyond Harbor Island. The age groups of those persons sampled varied. The samples were analyzed in April and May of 1980 and indicated that five persons of the 30 tested had blood lead levels above 35 ug/dl and, as a condition of the study, required testing. The Department of Social and Health Services considered 0-40 ug/dl an acceptable range for occupationally and environmentally exposed individuals. The followup of the five study subjects with higher levels in June/July 1981 indicated blood lead levels to be in the range of 11-17 ug/100 ml. The results of this study are considered to be inconclusive since no one person surveyed was associated with or employed on Harbor Island.[9,10]

The Sea Mar Clinic, in June through October 1984 conducted a blood lead level screening of 800 persons living in the South Park Area. South Park is a community located approximately 3 miles south of Harbor Island, outside of the study area. The predominantly northerly winds and the downwind location of South Park from Harbor Island could foreseeably have a potential air quality impact on the community.[1] The results of the study demonstrated very low blood lead levels within acceptable ranges.[11] These results were not available in a published form at the time of this investigation.

The Washington Department of Labor & Industry monitored air and blood lead levels at the lead smelter for the period of 1973 through 1983. Both inside and outside ambient air lead levels were periodically monitored in addition to blood lead levels. By 1983 the ambient air levels were reportedly down and blood lead levels of employees were also reduced, probably as a result of tighter controls and better health and safety programs and policies. In 1973, an estimated 60 ug/dl was an average blood lead level with extremes ranging up to 80 and over 100 ug/dl. By 1983, few people were above 50 ug/dl.[12] The Department of Labor & Industry plans to monitor persons at the lead oxide and lead fabrication facility at the site of the smelter.

In 1980, the Department of Education and Health Services completed a health hazard evaluation requested by Liberty Equipment Air Supply Company located at 2744 16th Ave. SW. Seven employees were screened for lead exposure and all ranged between 18-23 ug/dl, within the acceptable range of occupational and environmental exposure.[13]

Texaco and Shell on Harbor Island have also monitored employees for local lead exposure. A reduction in blood lead levels since 1977 appears to have occurred among Texaco Workers. In January, 1977, the highest blood lead level at Texaco was determined to be 51 ug/dl. In August of 1977 the highest detected level was 30 ug/dl and in September of 1981, the highest level was 21 ug/dl.[5]

## 6.4 TOTAL SUSPENDED PARTICULATE EMISSIONS

Total Suspended Particulates (TSP) in the Harbor Island area has exceeded the national annual primary standard in the past. By the end of 1983 this standard had been met in Washington; however, the Harbor Island-Duwamish Valley Area and the Tacoma Port area consistently record the highest concentrations. These areas exhibit a high degree of industrial, vehicle, and construction activity, and the potential to exceed the standard remains. The 1983 annual geometric means for the study area ranged from 65 to 75 $ug/m^3$. The primary national annual geometric mean standard is 75 $ug/m^3$.[1] Soil and road dust, wood combustion particles, and transportation dust have been determined to be the largest source contributors (69 percent) to the ambient TSP mass. The Lone Star Portland cement manufacturer is the largest industrial source of TSP in the study area emitting over 300 tons per year.[14]

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# 7.0 BIOTA INVESTIGATION

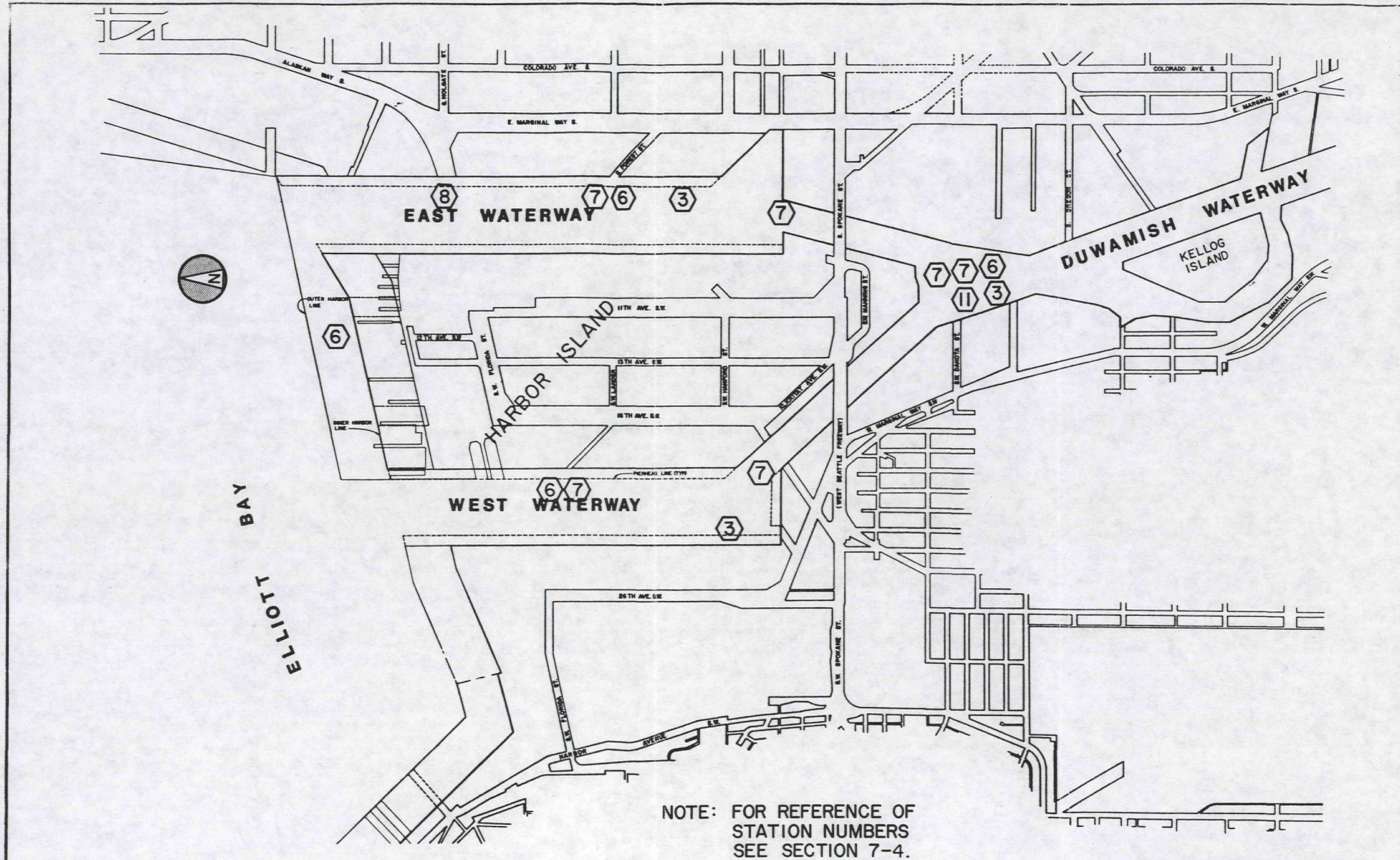
## 7.1 FAUNA

### 7.1.1 Sediment Bioassays

Sediment bioassays using developmental stages (eggs and larvae) of fish and invertebrate species have proven to be a useful indicator of toxic effects. Numerous research has shown that the embryonic and early juvenile life stages are particularly sensitive to the toxic effects of many trace environmental contaminants.[1] Some of these contaminants are commonly present in the industrialized areas of Puget Sound. Also, the reproductive potential of certain species may be inhibited by trace levels of toxicants that appear harmless or sublethal in tests of adult organisms.[1] Therefore, the sediment bioassay tests conducted in Puget Sound biota are used as a measure of relative toxicity as indicated by a sensitive organism or life stage. They are not intended to be an absolute measure of the environmental effect that would occur in nature.

The amphipod bioassay is a bioassay that is currently popular for testing potentially contaminated sediments. This test follows standardized procedures[2] and has proven to be an indicator of environmental quality. The amphipod Rhepoxynius abronius that is commonly used as a test organism lives in the surface sediments of shallow subtidal habitats in Puget Sound. This organism is a desirable test organism because of its burrowing behavior, which maximizes its time spent in the sediment and therefore contact with the contaminants. The amphipod bioassay has the undesirable feature that Rhepoxynius abronius is apparently sensitive to sediment characteristics other than contaminants making interpretation of results subjective. Other organisms or tissues used in bioassay tests conducted on sediments from the Harbor Island vicinity include oyster larvae, polychaetes, surf smelt, blue gill fry cells, and rainbow trout gonad cells.

7.1.1.1 Review of Existing Data. Station locations where sediment samples were collected for various bioassay test studies are summarized in Figure 7-1. One of the most recent studies involving sediments from the Harbor




NOTE: FOR REFERENCE OF STATION NUMBERS SEE SECTION 7-4.

SCALE: 1" = 1200'

SAMPLING LOCATIONS
OF SEDIMENT BIOASSAY STUDIES
PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE WASHINGTON

FIGURE 7-1

Island and vicinity included a series of bioassay tests of reproductive impairment of Puget Sound biota.[3] This study, conducted by Chapman et al., 1983, included a station in the East Waterway, West Waterway, and south of Harbor Island near the Diagonal Way Combined Sewer Overflow (CSO) (Stations 21, 26, and 29, respectively). Five replicate samples were collected at each station and composited to obtain a sample that was more representative of each area where the station was located. Bioassay tests conducted with the composited sediments included oyster larvae toxicity, surf smelt egg and larvae toxicity, polychaete life cycles, and <u>in vitro</u> cell reproduction.

The results of this study are summarized in Table 7-1. The percentage of abnormal larvae in the oyster larval bioassays of sediments from the three Harbor Island stations exceeded the single sample marine water quality criterion of 20 percent larval abnormalty.[4] The survival rates agreed with the data on abnormalties and were extremely low for stations 21, 26, and 29 (2.5, 6, and 13 percent, respectively). The authors concluded that based on the oyster larvae bioassays the three Harbor Island stations exhibited high toxicity.

The results of the surf smelt eggs and larvae tests were unclear. Many of the eggs were covered with a coating of fine sediment, which made it impossible to accurately assess development in terms other than hatching and larval survival. Tests of the sediment from East Waterway sediment yielded an exceptionally low hatching success (0 percent) (Table 7-1). Premature hatching was observed in one of the replicate tests of the sediment from the Diagonal Way station. The 10-day larvae survival rate was exceptionally low (0 percent) for the sediment tested from West Waterway. In summary, sediments from all three of the Harbor Island stations demonstrated negative biological effects in the smelt egg and larvae bioassays.

Life cycle test data for the polychaete <u>Capitella capitata</u> are summarized in Table 7-1. The sediment tested from East Waterway showed evidence of toxic effects through abnormal larval metamorphosis and significantly slower growth. The sediment tested from West Waterway also showed evidence of toxic effects through abnormal larval metamorphosis and low survival in the whole sediment tests (results of whole sediment tests

TABLE 7-1. SUMMARY OF DATA FROM CHAPMAN ET AL. 1983.[3]

| Station No. | Location | Sediment Characterization: % Water | % Soluble | % Extract[a] |
|---|---|---|---|---|
| 21[b] | West Waterway | 52.0 | 51 | 0.436 |
| 26 | East Waterway | 50.5 | 54 | 0.961 |
| 29 | Diagonal Way | 50.7 | 59 | 0.483 |

| Station No. | Location | Oyster Data: % Abnormal | % Relative Survival |
|---|---|---|---|
| 21 | West Waterway | 78 | 2.5 |
| 26 | East Waterway | 50 | 6.0 |
| 29 | Diagonal Way | 86 | 13.0 |

| Station No. | Location | Surf Smelt Data: % Optic Develop. | % Larvae Hatch | % 10 day Larvae Survival |
|---|---|---|---|---|
| 21 | West Waterway | 60 | 22 | 0 |
| 26 | East Waterway | 17 | 0 | 0 |
| 29 | Diagonal Way | 23 | 20 | 20 |

Polychaete Life-Cycle Data (from Sediment Elutriates)

| Station No. | Larvae Mortality During Metamorphosis | % Larvae Survival | Growth Rate (mm/d): To Day 16 | Growth Rate (mm/d): To Day 29 | Days to First Observed Eggs: Produced | Days to First Observed Eggs: Laid | Survival To Day 26 |
|---|---|---|---|---|---|---|---|
| 21 | 1 | 80 | 0.29 | 0.33 | 23 | 37 | 75 |
| 26 | 4 | 75 | 0.33 | 0.29 | 19 | 37 | 75 |
| 29 | 0 | 80 | 0.34 | 0.33 | 19 | 35 | 75 |

Cell Proliferation

| Station No. | Absolute Conc. Tested (mg/ml)[c] | | | | | | Relative Toxicity[e]: RTG-2 | BF-2 |
|---|---|---|---|---|---|---|---|---|
| 21 | 0.51 | 2.5 | 5.1 | $\underline{13}$ | $\underline{26}$ | $\underline{38}$[d] | 2 | 0 |
| 26 | $\underline{0.53}$ | $\underline{2.7}$ | $\underline{5.3}$ | $\underline{13}$ | $\underline{27}$ | $\underline{40}$ | 4 | 0 |
| 29 | $\underline{0.59}$ | $\underline{2.9}$ | $\underline{5.9}$ | $\underline{15}$ | $\underline{30}$ | $\underline{44}$ | 4 | 0 |

a = Organic matter recovered from the sediments expressed as percent of dry weight sediments.

b = Sediment had strong $H_2S$ odor and no organisms were present in sample.

c = Underlining indicates concentrations that were inhibitory to RTG-2 cells. Inhibition of BF-2 cells did not occur in the sediment extracts from the three Harbor Island stations.

d = Indicates a concentration (38 mg/ml) that was cytotoxic.

e = Relative toxicity was scored as follows:
0 = no effect
2 = significant from 10-19 mg/ml
4 = significant from 1-4.9 mg/ml

are not presented in Table 1). The sediment tested from the Diagonal Way station appeared to be relatively non-toxic to Capitella capitata which exhibited significantly higher initial growth than was observed in any other tests including controls.

The results of the cell proliferation tests are also summarized in Table 7-1. Tests using blue gill fry (BF-2) cell cultures did not show a significant decrease in cell numbers as a result of exposure to any of the concentrations tested from the three Harbor Island stations. In contrast, rainbow trout gonad cultures (RTG-2) exhibited a decrease in cell numbers relative to controls and showed typical dose responses to increasing concentrations of sediment extract. Stations 26 and 29, from the East Waterway and Diagonal Way, respectively, appeared to have the strongest toxic effects at concentrations below 10 ug/ml.

Chapman, et al., 1983, summarized their results by calculating an overall ranking of the sections based on the reproductive impairment testing. The three Harbor Island stations were among the most toxic sites tested when compared using the overall ranking. In comparison to the data from the same areas presented in an earlier study[5], the East and West Waterway stations appear to be more toxic than originally anticipated. One of the possible explanations for the difference in results is the patchy distribution of toxicants that is commonly found in the sediment. The earlier work (1982) was based on a single grab at each station, whereas the 1983 work was based on a composite of five replicate grabs. This difference in sampling design may explain the difference in results.

Amphipod bioassay tests were also conducted on sediments collected from 17 stations around Puget Sound in 1981.[6] These tests included sediments from four locations in the Harbor Island vicinity: West Waterway, East Waterway, north of Harbor Island, and south of Harbor Island (Figure 7-1). The amphipod Rhepoxynius abronius was used as the test organism. Tests included lethal effects (mortality after 10-day exposure to sediments) and sublethal effects (moribund organisms, or failure to burrow after 10-day exposure).

Based on the lethal effects portions of these tests, two of the Harbor Island stations (south Harbor Island and West Waterway) were determined to be significantly more toxic than the control station (West Beach on Whidbey Island). In fact, the sediment from the West Waterway caused mortality that was significantly higher than the other 15 stations indicating a relatively high toxic environment. The results of the sublethal effects tests indicated that tests using sediments from three of the Harbor Island stations (West Waterway, south Harbor Island and north Harbor Island) had a significantly higher percentage of moribund animals among survivors. No results were available from the East Waterway station due to high control group mortality at the time this sediment was tested.

Additional amphipod bioassay tests were conducted on sediments from the Harbor Island vicinity in November of 1983.[7] This study included testing sediments from about 6 different locations in West Waterway, East Waterway and south of Harbor Island (Figure 7-1). Mortality rates reported in these tests were all less than 40 percent, or considerably lower than previous amphipod bioassay tests conducted in 1981 on sediments from similar areas of Harbor Island. The author attributed the low mortality to the time of year the study was conducted and to seasonal changes in the sensitivity of the test organism.[7] Tests were conducted in November, a time of year when the organism is preparing to overwinter and is not as sensitive as it would be in the spring time.

The Port of Seattle contracted with an independent consultant to conduct amphipod and oyster larvae bioassays on potential dredge material from the Pier 32 area of East Waterway.[8] Sample locations for this study are also presented in Figure 7-1. Amphipod lethality tests were conducted on whole fresh (unfrozen sediments) and followed the protocol of Swartz et al.,[9,10], which included 10 day exposure to test sediments. Oyster larvae bioassays included determining percent survival (lethal effects) and percent abnormality (sublethal effects).

In 18 of the 25 sediment samples tested using amphipod bioassays, the survival rate was significantly lower than controls. In 21 of the 22 sediment samples tested using oyster larvae bioassays, the level of abnormalties was significantly higher than in controls. All samples classified as toxic by the amphipod bioassay were also classified toxic by the oyster larvae bioassay. The fact that the oyster larvae bioassay classified an additional four samples as being toxic is not surprising since it is reported to be a more sensitive test. The conclusions from this study were that 18 of the 25 samples tested did not meet the biological criteria for open water disposal. Those samples that passed the criteria for open water disposal typically were collected at greater depths from the same areas as those samples that failed the criteria.

Sediment bioassay tests were conducted on sediments from the vicinity of Harbor Island as part of Metro's Toxicant Pretreatment Planning Studies.[11] One station was located at the south end of Harbor Island (Figure 7-1) where sediment samples were collected in March of 1982 for oligochaete respiration (sublethal effects) tests, and September and October of 1982 for amphipod bioassay tests (lethal effects). The oligochaete respiration test showed no significant difference between Harbor Island sediments and the control samples. The amphipod bioassay indicated there was a significant difference between the sample from south of Harbor Island and control samples.

Other bioassay studies have been conducted on sediments from the Harbor Island area[12,13,14,15]. The results of these studies are not presented in this summary for a variety of reasons. Two of the studies[13,14] used inappropriate methods and were determined to be inadequate for use in describing the sediment toxicity in the Harbor Island vicinity. The inadequacies of these studies are summarized by a review of pertinent literature for the Elliott Bay Toxics Action Plan, conducted by Tetra Tech[16]. Two of the studies[12,15] are relatively outdated and used techniques that have been refined and upgraded considerably.

A recent review of existing data, conducted by Tetra Tech[16], examined the extent of toxic contaminants in Elliott Bay (including Harbor Island). Included in this review is a summary of the sediment bioassay data available for the Harbor Island area. Their summary included a comparison of amphipod mortality and oyster abnormality measured in tests with sediments from the Harbor Island vicinity versus tests using reference sediments from Bowman Bay and West Beach, Washington, and Yaquina Bay, Oregon. They found that the mean elevations above reference (EAR) values for amphipod mortalities from sediments at East Waterway, West Waterway, and Kellogg Island were 6.8, 3.8, and 3.1, respecitvely. These results are significantly different from average reference conditions. The mean EAR for amphipod mortality from the north Harbor Island area was 0.9, which was not significantly different from reference conditions.

The mean EAR values for the oyster abnormality tests with sediments from north Harbor Island, East Waterway, West Waterway, and Kellogg Island area were 1.0, 6.1, 12.8, and 0.3, respectively. The north Harbor Island and East Waterway sediments were significantly different from average reference conditions.

### 7.1.2 Fish Pathology and Bioaccumulation

The Duwamish/Green River system supports approximately 40 different species of fish. Marine species abundant in the area include Pacific staghorn sculpin (*Leptocottus armatus*), starry flounder (*Plactichthys stellatus*), English sole (*Parophrys vetulus*), Pacific snakebelly (*Lunpenus sagitta*), shiner perch (*Cymatogaster aggregata*), and Pacific herring (*Clupea harengus*). This area also provides important rearing habitat for herring, perch, sculpins, and other fishes. The Green/Duwamish River system contains viable runs of fall chinook, coho, and chum salmon, steelhead and cutthroat trout, and Dolly Varden char.[17] Utilization of the Waterways and adjacent Elliot Bay by juvenile salmonids for feeding and rearing has also been documented.[18,19]

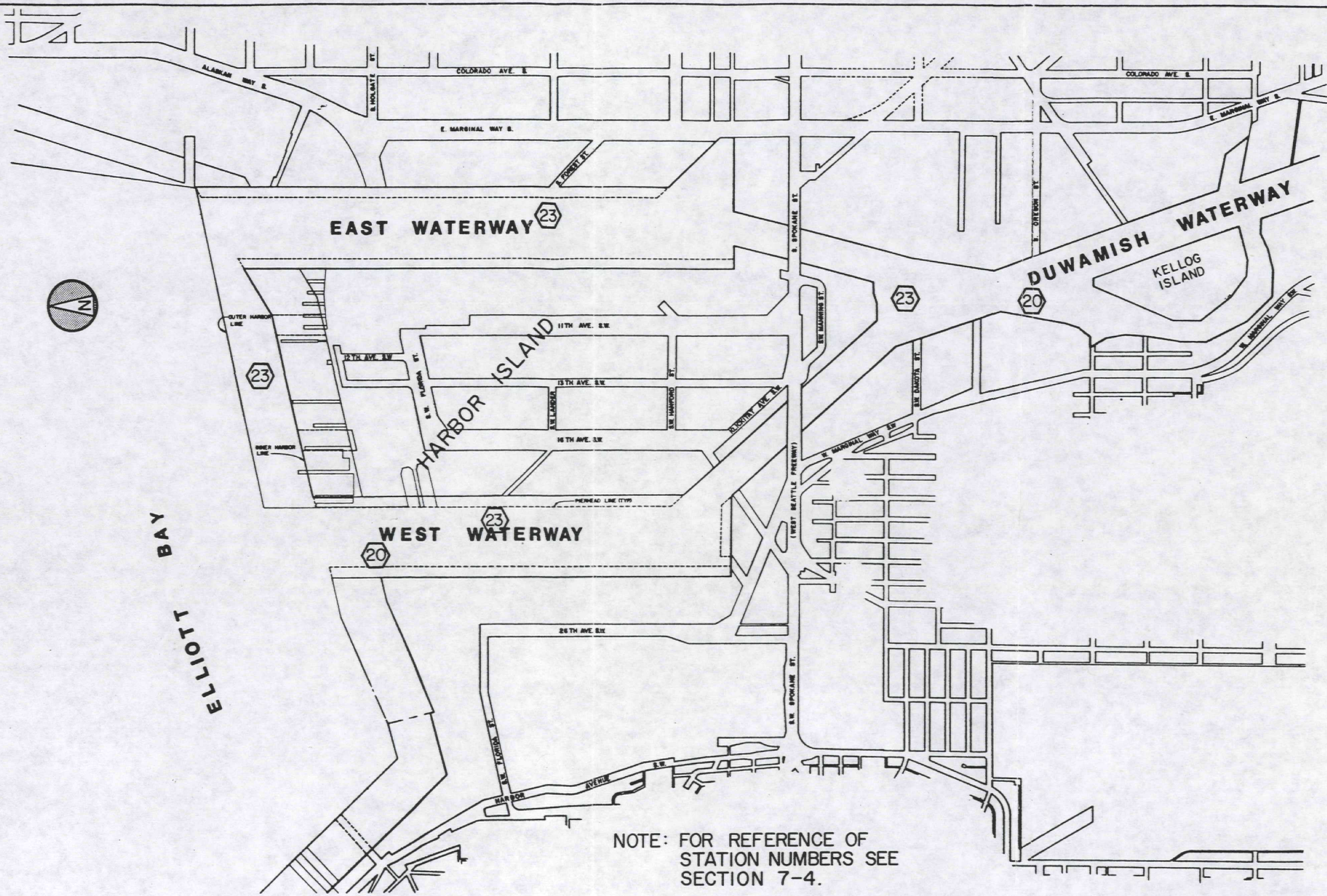
Chemical pollutants enter the Duwamish River from a number of sources and many are subjected to chemical and biological transformation in the aquatic environment, which results in a host of new compounds. Concern for the effects of these chemicals on aquatic animals has prompted investigations on health of demersal fishes in the Duwamish Estuary, but little is known about their toxicity.

Demersal fishes are used as indicator organisms of toxic contamination within the sediment because they are in close contact within the sediment, they are territorial, and they tend to form discrete localized subpopulations. Liver neoplasms, skin papillomas, fin erosion, and non-neoplastic liver abnormalties are the types of pathological conditions that have been observed in flatfish (primarily English sole and starry flounder) in the Duwamish estuary.[19,20,21] These pathological conditions may be associated with parasites and microorganisms that are not related to toxic pollutants, or they may be a result of unknown etiology (referred to as idiopathic lesions). Etiological relationships between chemical pollutants and diseases of fishes have not been verified, but microbiological and histological evidence suggest that microorganisms are not the direct cause.[19] Therefore, environmental pollutants are a likely etiological agent.

Other factors such as migration, population (age-class) structure, and prey/food sources need to be further evaluated before the cause of pathological conditions can be confirmed. In instances where pathological conditions, tissue accumulation of toxicants and sediment chemistry are positively correlated, the pathological condition is commonly considered to be a useful indicator of environmental contamination.

7.1.2.1 Review of Existing Data. Fish pathology field and laboratory investigations were conducted between October 1978 and October 1980 in four estuary areas of Puget Sound, including the Duwamish estuary.[20] Two of the seven Duwamish estuary stations were located in the Harbor Island vicinity (Figure 7-2). Fish captured were examined externally for visible abnormalities, necropsied, and examined using histopathological procedures. Laboratory studies were also conducted by collecting fish from the reference areas and exposing them to and/or injecting them with sediment extracts from the Duwamish estuary.

The results of the visual and histopathological examinations were presented primarily for the Duwamish estuary as one uniform area rather than as data from the specific stations. Therefore, it is difficult to discuss any conclusions from the two stations in the Harbor Island vicinity. The prevalence of degenerative, potential preneoplastic, and true neoplastic liver lesions in English sole from the Duwamish was significantly higher than any of the other areas tested (McAllister Creek, Snohomish River and Lake Washington Ship Canal). Twelve of the 16 major types of hepatic lesions were found only in English sole from the Duwamish Waterway and Lake Washington Ship Canal.




NOTE: FOR REFERENCE OF STATION NUMBERS SEE SECTION 7-4.

SCALE: 1" = 1200'

SAMPLING LOCATIONS OF FISH PATHOLOGY AND BIOACCUMULATION STUDIES

PRELIMINARY INVESTIGATION - PHASE I
HARBOR ISLAND
SEATTLE, WASHINGTON

FIGURE 7-2

A comparison of liver lesion prevalence was also made among the Duwamish stations. In general, the prevalence of liver lesions in sole was lower at the two Harbor Island stations. The one inconsistency to this general trend was the high prevalence of megalocytic hepatosis at the West Waterway station. The morphology of this lesion suggests it is induced by naturally occurring and xenobiotic chemical species.

Gill lesions were also significantly more prevalent in sole from the Duwamish than from reference areas. The lowest percentage (36.5) of sole free from microscopically detectable idiopathic and parisitic lesions occurred in sections of the gills examined from the Duwamish stations. No data were presented for gill lesion comparisons among the Duwamish stations. The highest prevalence of heart, gastrointestinal tract, and kidney lesions varied among all four of the sampling areas, although examination for lesions and the number of lesions present were not as extensive for these organs as for the liver and gills.

The authors concluded that most of the liver lesions were probably the result of long term exposure to one or more environmental factors. This conclusion was based on the fact that the average age of English sole with liver lesions was 4-6 years. However, certain idiopathic liver lesions were detected in fish as young as one year of age.

The laboratory studies exposing English sole to contaminants found in sediments from the Duwamish did not induce the pathological conditions observed in English sole from the Duwamish. The lab studies did demonstrate that sediments from the Duwamish had certain components, that were toxic to sole, that were not present in reference sediments. Further lab experiments using radioactively labeled BaP (benzo[a]pyrene), a carcinogenic polynuclear aromatic hydrocarbon, demonstrated that this component was readily taken up directly from contaminated sediment by English sole.

In an earlier study, McCain et al.[21] measured the incidence of liver hepatomas in English sole collected at eight stations in the Duwamish estuary. The results showed an overall average of 32 percent of the livers examined histologically had hepatomas. Data were not reported for individual stations, and insufficient numbers of fish were examined to establish a geographical distribution in the Duwamish.

Tetra Tech's recent review [16] of available data for the Elliott Bay Toxic Actions Plan includes a summary of fish pathology data. Their analysis includes determining mean elevations above reference (EAR) levels, similar to the type of analysis conducted for sediment bioassays, for various areas of Elliott Bay. Mean EARs for neoplasms and preneoplasms were significantly higher for English sole from the Harbor Island/Duwamish region. Mean EARs for megalocytic hepatosis were also significantly higher for both English sole and rock sole in the Harbor Island vicinity compared to reference levels.

Wellings et al.[22] studied fin erosion disease of starry flounder and English sole in the Duwamish River estuary. Fin erosion disease is a progressive destruction of fin tissue observed in a number of freshwater and marine fishes. Two of their seven stations were located in the Harbor Island vicinity (Figure 7-2, same station locations as McCain, et al.[20]). The incidence of fin rot varied over time and among station. No comparisons were made between the incidence of fin erosion at the Duwamish stations with reference stations. The etiology of fin rot is unknown, but Malin et al. suggest that multiple environmental variables (such as chemical pollutants, physical factors, mechanical injury, etc.) act in some combination with genetic constitution to cause an incidence of disease within a population.

Fish and invertebrates accumulate many of the pollutants from aquatic environments. Depending on an organism's mobility and life history characteristics, the bioaccumulation of toxicants in tissues may be used as an indicator of environmental degradation. Very little bioaccumulation data has been collected in samples from the Harbor Island area.

A four-year interdisciplinary study investigating relationships between pollutants, disease, and bioaccumulation of toxicants in fish from Puget Sound is summarized by Malins, et al.[23] This study included four stations in the Harbor Island vicinity where sediment samples and fish samples were collected (Figure 7-2). The organs with the greatest number of lesions were the liver, kidney, and gills. Two major classes of lesions were detected: lesions associated with parasites or microorganisms, and idiopathic lesions (unknown etiology). Idiopathic lesions were detected most frequently in the liver. The higher prevalence of hepatic neoplasm (an idiopathic lesion) were in English sole from the Duwamish Water and Everett Harbor.

Sediment chemistry results from this study[23] indicated that high concentrations of lead, arsenic, and mercury were present in the sediments from the Harbor Island stations. However, concentrations of these same chemicals and the more metabolically labile compounds (e.g., aromatic hydrocarbons), were generally lower in fish tissue than in sediments. Concentrations of metabolically resistent organic compounds (e.g., PCBs, hexachorabutadiene (HCBD), and hexachlorobenzene (HCB)) were found in livers and muscle of English sole and were generally high in comparison to the concentrations in sediments. Because of these differences in the disposition and metabolism of chemicals, no attempt was made to use tissue burdens as indicators of exposure to the sediment-associated chemicals.

An assessment of the water quality within the Duwamish estuary included a summary of the available data pertaining to selected toxic residues in Duwamish biota.[24] This summary did not break down the data collected from various areas in the Duwamish but rather pooled the data to include the entire Duwamish estuary (Table 7-2). Therefore, it is difficult to discern the information pertinent only to the Harbor Island vicinity. In their discussion on data pertaining to lead concentration, they point out that mussel samples collected near Harbor Island had a 30-fold increase in lead content over Puget Sound background levels.[24,25] Therefore, a significant portion of the lead burden in the Duwamish is thought to be bioavailable to the lower trophic levels. Higher trophic levels did not appear to be as affected as evidenced by fish tissue samples that did not contain significantly higher concentrations of lead.

The PCB data summarized in this report[25] indicate a significant decrease in whole-body PCB residues in fish (English sole, Pacific staghorn sculpin, and starry flounder) from the Duwamish from 1972-1979. These results are consistent with a decrease in PCB concentration in sediment observed during the period 1973 to 1982.

A summary of the bioaccumulation data conducted for the Elliott Bay Toxics Action Plan[16] includes a comparison of chemical indicators in reference areas versus the north Harbor Island vicinity. Concentrations of

TABLE 7-2. SELECTED TOXICANT RESIDUES IN DUWAMISH BIOTA (Parentheses refer to elevation above Puget Soun background[a] levels; "n.s." denotes that Duwamish residues are not significantly (P=.05) higher than background). Table taken from Harper-Owes, 1983.[25]

| Parameter (units) | Annelids, Crustaceans, and Molluscs | Crab Hepatopancreas | Bottom Fish[b] | Salmon Muscle | Sediments[c] (areal-weighted) |
|---|---|---|---|---|---|
| Metals (mg/kg) | | | | | |
| Arsenic | - | - | 5.4 (?)[d] | - | 97. (22x) |
| Cadmium | 0.75 (n.s.) | 0.40 (n.s.) | 0.04 (n.s.) | - | 3.6 (2x) |
| Chromium | 1.9 (n.s.) | 1.6 (n.s.) | 1.1 (n.s.) | - | 30. (2x) |
| Copper | 7.7 (n.s.) | 35. (n.s.) | 2.8 (n.s.) | - | 83. (6x) |
| Mercury | - | - | 0.34 (n.s.) | - | 0.55 (12x) |
| Lead | 6.2 (30x) | - | 0.44 (n.s.) | - | 280. (22x) |
| Silver | - | 1.2 (n.s.) | 0.01 (n.s.) | - | 1.4 (2x) |
| Zinc | 24. (n.s.) | 28. (n.s.) | 7.4 (n.s.) | - | 250. (7x) |
| Organics (ug/kg) | | | | | |
| Total PCB | 250. (1979) | 9600. (?) (1979) | 2,310. (51x)(1972)<br>560. (12x)(1979) | 240. (14x)(1975) | 720. (65x) |
| Total DDT | 5.0 (1979) | 960. (?) | 110. (8x) | 34. (5x) | 14. (36x) |
| Carcinogenic PAH | 64. (10x) | 8. (?) | 10. (?) | - | 1,700. (38x) |
| Total Selected PAH | 610. (8x) | 200. (?) | 46. (3x)(liver only) | - | 3,600. (34x) |
| Naphihalene | 57. (17x) | 33. (?) | 14. (14x)(liver only) | - | 77. (11x) |
| Hexachlorobenzene | 0.3 (?) | 0.9 (?) | 10. (7x)(liver only) | - | 0.12 (5x) |

[a] Background sites include: Case Inlet, Hood Canal, Meadow Point, Nisqually Delta, and Port Madison.
[b] Estimated from a regression of whole-body PCB residues vs. time and liver/somatic characteristics
[c] Statistical comparisons not performed on sediment data due to large non-random spatial variation
[d] Question marks indicate that data is insufficient to perform statistical comparisons.

low molecular weight polyaromatic hydrocarbons and PCBs from the north Harbor Island area were significantly elevated (7-9 times) above reference levels. Concentrations of high molecular weight polyaromatic hydrocarbons were also higher than reference levels (3-4 times), but not significantly.

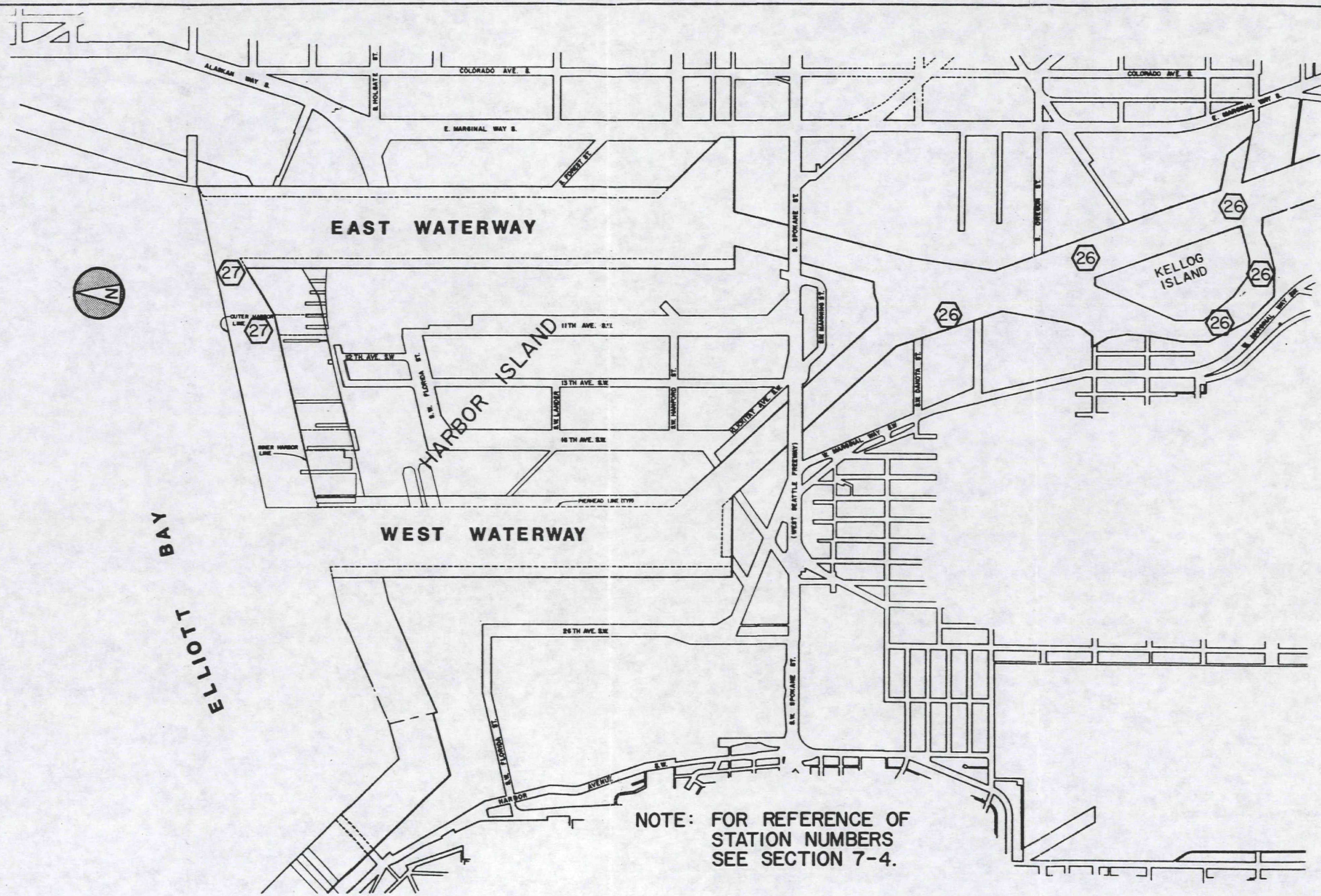
### 7.1.3 Benthos

Relatively little pertinent benthos data exist for the Harbor Island vicinity. A study of the benthos in the Kellogg Island area was published in 1980 for the Port of Seattle,[26] and some benthos samples were collected from the north Harbor Island area as part of the Renton Sewage Treatment Plant Project, Duwamish Head Study[27] (Figure 7-3). No useful recent benthos data are available from the East and West Waterways.

The mean total taxa for the Kellogg Island and north Harbor Island stations was relatively low (29 and 76, respectively).[16] In Tetra Tech's comparison of these data they analyzed a variety of benthic variables (mean total abundance, mean total taxa, mean amphipod abundance, and mean dominance index) . Areas of Elliott Bay were then ranked based on the mean value for the above mentioned benthic variables. The Kellogg Island area had the lowest ranking reflecting the fewest number of taxa and individuals in the benthic community.[16] Comparison of the rank values indicated that Kellogg Island had one of the most degraded benthic communities in Elliott Bay.[16]

## 7.2 FLORA

Relatively little information is available about the flora of the Harbor Island area. The available information is descriptive and does not address the effects of toxic pollutants on the flora. Riparian vegetation is predominantly lacking due to historical shoreline development. Upland areas and banks are vegetated primarily by mixed grasses and shrubs.[28] Kellogg Island is one of the few biologically important terrestrial habitat areas remaining in the Duwamish estuary. The diversity of flora at this location provides habitats for small mammals, birds, and waterfowl.[28]




SCALE: 1" = 1200'

SAMPLING LOCATIONS OF BENTHOS STUDIES

PRELIMINARY INVESTIGATION-PHASE I
HARBOR ISLAND
SEATTLE WASHINGTON

FIGURE 7-3

## 7.3 SUMMARY

Existing data regarding aquatic and benthic biota at the Harbor Island study area clearly indicate the organisms are under environmental stress. The incidence of mortality and deformities in bottom fish and invertebrate samples taken from the study area is significantly higher than in samples from reference locations. Bioassay tests indicate toxicity of the water and sediment to test organisms. Evidence suggest that toxicants from the Harbor Island study area are a significant cause of the documented adverse environmental effects.

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# 8.0 PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS

This section relates the current conditions data presented in the previous sections to potential human health effects and environmental concerns. Potential receptors and effects of the lead from the Harbor Island smelter as well as other pollutant releases from the study area (site) are discussed. The available existing data suggest that the sources of pollutant releases within the Harbor Island site could cause adverse human health or environmental effects in nearby areas. However, available data are not sufficient to conclude that such a cause and effect relationship actually exists.

## 8.1 POTENTIAL RECEPTORS

The ambient air lead concentrations resulting from past activities of the lead smelter on Harbor Island exposed workers and families of workers to unhealthy levels of lead. Residents in areas downwind (south) of the facility also were considered to be potential receptors of lead in the air. Since the national ambient air quality standard for lead has been met recently, the potential receptors of lead emissions are no longer exposed to levels of lead which could be expected to cause health complications. However, lead and other contaminants entrained into the air from soil and dust may still be a health concern for workers.

Contaminants in soil or on paved lots are potentially transported via groundwater percolation and runoff to drainage into the Duwamish River and Elliott Bay. Presently there are no uses of the marine/estuary water or the shallow groundwater aquifer in the study area for human consumption or agriculture. Therefore, the greatest potential impact from hazardous concentrations of heavy metals and organic pollutants present in the sediment and water column in the Harbor Island vicinity is to aquatic organisms inhabiting this area. Organisms in close contact with sediment, such as benthic and epibenthic invertebrates and certain species of bottom fish, are likely to receive the greatest exposure to the highest levels of contaminants. These organisms would be considered as primary receptors of the bioavailable toxicants present in the sediments.

Many of the benthic and epibenthic invertebrates serve as a food source for other species and fish living in or migrating through the site. The extent to which the toxicants are passed along the food chain is not clearly understood, but considering that bioaccumulation of toxicants does occur in invertebrates, it is reasonable to expect that some level is passed along to the consumer of these invertebrates. Water birds and mammals which inhabit the Harbor Island vicinity are also potential receptors of toxicants present in the sediment, water column and their food sources. Finally, humans could become receptors of bioaccumulated toxicants through consumption of contaminated fish or invertebrates.

## 8.2 PUBLIC HEALTH IMPACTS

Human exposure to lead primarily occurs from inhalation of dust particles and other air contaminants and through ingestion of food, water or other objects contaminated with lead components. At low levels, once lead is in the blood and tissues, cumulative amounts may reach levels where symptoms and disabilities occur. Lead exposure produces red blood cell disorders and harmful effects to the central nervous system.[1] Health officials concede that a 30 ug/dl blood lead level in children should not be exceeded,[2] and the Center for Disease Control in Atlanta, Georgia recently determined that a 35 ug/dl blood lead level constitutes lead poisoning.[3]

Acute health problems associated with lead exposure on Harbor Island are not apparent in the available studies. Since the operations of the lead smelter have terminated, the ambient lead concentration has been reduced. The Harbor Island area achieved attainment of ambient lead standards in 1984, meeting the national quarterly standard of 1.5 $ug/m^3$. However, high levels continue to be detected on an intermittent basis.[2] The Washington Department of Social and Health Services has indicated that since 1980 the blood lead levels in the study area show no evidence of increasing.

High concentrations of lead or other toxicants in study area soils could present a health hazard to workers involved in construction of roads, subsurface utilities, structures, or other facilities where the soil is disturbed. However, data about the areal extent of soil contamination at the Harbor Island site is relatively limited. Therefore, site-specific studies should be conducted prior to initiating activities that could disturb soil in areas where hazardous substance releases are known/suspected to have occurred.

The primary approach to evaluating the potential adverse effects of contaminated water quality on public health is to determine the effects of consuming contaminated food sources such as fish or invertebrates (clams, crabs, mussels, etc.) that may be present in the Harbor Island vicinity. Comparing human health water quality contaminant criteria with contaminant levels measured in the water column does not provide a realistic evaluation of public health impacts because ingestion of water from Duwamish estuary/Harbor Island area is extremely unlikely. A similar analysis using sediment concentrations of contaminants is equally invalid due to the unlikely probability of humans injesting sediments.

Harper-Owes' water quality assessment of the Duwamish[4] summarized the tissue concentrations for certain heavy metals and organics in Duwamish bottom fish and compared them to EPA criteria.[5] The EPA criteria is based on an average consumption of 6.5 gm/person/day. Thus individuals who consume a higher quantity than this are exposed to a higher risk than what is used in the comparison. The results of this comparison are summarized in Table 8-1. The toxic concentrations used in this comparison were measured for fish in all of the Duwamish estuary, not just Harbor Island vicinity. Individual data from Harbor Island stations were not available, and due to the transient nature of the bottom fish used in the comparisons such site-specific comparisons are not likely to be valid.

The results of the metal criteria comparison indicate that whole body tissue concentrations are at least eight times lower than the criteria maximum for all metals except arsenic. Arsenic levels in Duwamish bottom fish appear to exceed the EPA criteria by over 1,000 fold. However, interpretation of the arsenic comparison should be viewed with caution because of insufficient data on arsenic levels in fish collected from reference sites.[6] Since muscle tissue concentrations of all metals, except arsenic, in Duwamish bottom fish are not significantly different from bottom fish collected at Puget Sound reference sites, ingestion-related public health impacts of these metals are probably negligible. This conclusion is based on muscle tissue concentrations and may not be valid for ingestion of organs (i.e. liver) that tend to concentrate the levels of toxicants.

The results of the organic pollutant criteria analyses indicate that PCB levels pose the greatest threat to human health based on ingesting contaminated fish. Even though recent trends indicate a decrease in PCB concentrations in bottom fish tissue from the Duwamish, PCBs remain the significant organic pollutant present in bottom fish.

Bottom fish residues of DDT in the Duwamish are about eight times greater than Puget Sound background level.[4] Although the manufacture of this substance has been banned in the United States for about ten years, sediment and biotic residue concentrates do not reveal any significant decline over the seven year period of record analyzed.[4]

TABLE 8-1 HUMAN HEALTH CRITERIA FOR HARVESTING/INGESTION OF CONTAMINATED AQUATIC ORGANISMS[a]

| Pollutant | No effect | EPA Criteria[b] 1/10[6] cancer increment[c] | FDA Internal Guidelines | Observed Conc. in Duwamish Bottom Fish (whole-body (mean + std. dev.) |
|---|---|---|---|---|
| Arsenic | 0 | 0.77 | - | 5400 + 500[d] |
| Lead | 28,000[e] | - | - | 400 + 520 |
| Mercury | 2,700[f] | - | 1,000 | 340 + 250 |
| Total PCB | 0 | 2.5 | 5,000[g] | 560 + 380 |
| Total DDT | 0 | 1.3 | 5,000 | 110 + 110 |
| Carcinogenic | 0 | 0.93 | - | -[h] |

[a]All units are ug/kg wet weight; 1979 levels.

[b]Derived from EPA, 1980[5], which assumed a mean ingestion of 6.5 grams per day of fresh water/estuarine fish and shellfish. EPA water quality criteria to protect human health (fish/shellfish consumption only) were multiplied by the bioconcentration factor used (by EPA) to formulate the criteria. (See EPA, 1980 for a complete description of the criteria).

[c]The edible fish tissue concentration which would result in an incremental increase of cancer risk over a person's lifetime at the rate of one in one million people. EPA, 1980[5] did not determine an "acceptable" risk level, but is presently considering risk levels between $1/10^7$ and $1/10^5$.

[d]Bottom fish from Puget Sound reference areas contain similar arsenic levels (Malins et al., 1982[6]), as do many fish collected in the open Pacific Ocean (A. Mearns, NOAA, personal communication).

[e]Tissue concentration resulting in a 10 ug/100 ml increase in blood lead level.

[f]Assuming an average consumption of mercury from ocean sources (e.g. tuna).

[g]Proposed FDA regulation is 2,000 ug/kg wet weight (200 ug/kg for infant food).

[h]No data on whole-body residues are available. However, the mean liver concentration in bottom fish is less than 10 ug/kg (Malins et al., 1980[7]) and is probably even lower in muscle tissue. Bottom fish are known to rapidly metabolize PAH (Varanasi and Gmur, 1981).[8]

Source: Reference 4.

## 8.3 ENVIRONMENTAL IMPACTS

The existing information indicates a number of environmental impacts due to the levels of toxicants in the sediment and water column in the Harbor Island area. These impacts have been demonstrated through sediment bioassay tests, fish pathology and bioaccumulation studies, and benthos investigations.

The results of the bioassay tests indicated that exposure to the sediments caused sublethal effects that were significantly greater in test organisms versus control groups. The bioassay tests did not indicate any acute lethal toxicities present. Examples of some of the sublethal effects measured are: a decrease in the ability of burrowing amphipods to burrow into the sediments, abnormal development of oyster larvae, a decrease in hatching rate of surf smelt eggs, and a reduction in cell proliferation of rainbow trout gonad cells and blue gill fry cells.

Fish pathology studies indicated that liver lesions and other pathological disorders were present in significantly greater numbers in selected biota from the Duwamish estuary and Harbor Island area versus Puget Sound reference sites. Although the origin of some of the idiopathic disorders can not be established without some uncertainty, several of the disorders have characteristics which link them to the toxicants which are most prevalent in the Duwamish estuary.

Bioaccumulation studies indicate a concentration of certain toxicants in the organs of selected biota collected from reference sites. Tissue bioaccumulation data summarized in Table 7-2 indicate that the concentration of some of the organic compounds in fish tissue actually exceeded the areal-weighted sediment concentration.[4] This is basically the converse of what was observed for the metals, which tended to be considerably lower in tissues than in sediments. The concentrations of organics may be higher in non-polar media such as lipids which are present in higher concentrations in biota than in sediments.[4] Conversely, metals tend to associate more with ionically charged sediment particles.[4] The impacts of organic pollutants may, therefore, be more serious to aquatic biota due to the organism's apparent ability to assimilate them easier than metals.

The limited benthos data from the Harbor Island area suggest a degraded benthic environment is present there. This conclusion is based on the low number of taxa present in the samples which indicate a lack of diversity. Identifying the cause of this degradation is not an objective of benthos sampling, but the fact degradation has occurred indicates an impact to the environment.

Water (column) quality data [1] summarized in Table 5-3 indicates that the concentrations of many of the metals (copper, lead and mercury) exceed chronic effect criteria established by EPA. The levels of organic pollutants measured in the water column did not exceed EPA chronic effect criteria.

Exposure of biota, surface waters and groundwater to excessive ambient air lead concentrations has been greatly reduced since the closure of the lead smelting operations. Further investigations of lead concentrations and other dust/air contaminant concentrations affecting the Harbor Island environment do not appear to be necessary at this time.

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**APPENDIX A**

SECTION 5 TABLES AND FIGURES

POLLUTANT CONCENTRATIONS

Table 1. DUWAMISH ESTUARY ANNUAL POLLUTANT INPUTS FOR DOCUMENTED SOURCES (1970-1980) (From Harper-Owes, 1983).

| | INPUTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameters (Units) | Upstream Green River | Renton Treatment Plant | Black River | Combined Sewer Overflow | Regional Stormwater | Direct Industrial Discharge | Atmospheric | Deep Alvection from Elliott Bay | Total Documented Inputs |
| Hydraulic Load ($m^3 \times 10^6$/yr) | 1,523. | 42. | 67. | 3.5 | 6.1 | 3.4[a] | 1.2 | 171. | 1,817. |
| Sediment (kg $\times 10^6$/yr) | 241. | 0.4 | 1.7 | 0.4 | 0.2 | <0.1[b] | 0.2 | 0.2 | 244. |
| Total Organic Carbon (kg $\times 10^3$/yr) | ? | 0.78 | 0.20 | 0.12 | 0.02 | 0.03 | <0.01 | <0.01 | 1.2 |
| Oil and Grease (kg $\times 10^3$/yr) | ? | 310. | ? | 38. | 18. | 6. | <1. | ? | 370. |
| Ammonia (as N) (kg $\times 10^3$/yr) | 134. | 588. | 39. | 3.2 | 0.3 | ? | ? | 7.9 | 770. |
| Arsenic (kg $\times 10^3$/yr) | ? | 0.09 | ? | 0.04 | ? | 0.78 | <0.01 | 0.26 | 1.2 |
| Cadmium (kg $\times 10^3$/yr) | 0.20 | 0.09 | 0.18 | 0.01 | 0.17 | 0.12 | <0.01 | 0.06 | 0.83 |
| Chromium (kg $\times 10^3$/yr) | 3.5 | 0.63 | 0.76 | 0.23 | 0.04 | 0.01 | ? | ? | 5.2 |

[a]Coolant water (non-recirculated) at a weighted mean temperature of 24.6 degrees C.

[b]< denotes "less than"; > denotes "greater than".

Table 1 (Continued). DUWAMISH ESTUARY ANNUAL POLLUTANT INPUTS FOR DOCUMENTED SOURCES (1970-1980) (From Harper-Owes, 1983).

| Parameters (Units) | INPUTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Upstream Green River | Renton Treatment Plant | Black River | Combined Sewer Overflow | Regional Stormwater | Direct Industrial Discharge | Atmos-pheric | Deep Alvec-tion from Elliott Bay | Total Documented Inputs |
| Copper (kg x $10^3$/yr) | 2.7 | 1.1 | 0.50 | 0.28 | 0.06 | 0.19 | 0.16 | 0.10 | 5.1 |
| Iron (kg x $10^3$/yr) | 5,400. | 17. | 250. | 15. | 530. | ? | ? | 10. | 6,200. |
| Mercury (kg x $10^3$/yr) | 0.75 | 0.011 | ? | 0.001 | ? | ? | ? | ? | 0.76 |
| Nickel (kg x $10^3$/yr) | <30. | 1.0 | 1.3 | 0.1 | ? | ? | <0.1 | ? | <32. |
| Lead (kg x $10^3$/yr) | 6.2 | 0.57 | 1.0 | 1.2 | 1.8 | 0.1 | 0.4 | 0.6 | 12. |
| Zinc (kg x $10^3$/yr) | 17. | 2.6 | 11. | 0.9 | 0.9 | 2.0 | 0.2 | 0.4 | 35. |
| Total PCB[c] (kg/yr) | ? | 2.9 | ? | 1.9 | 0.7 | ? | ? | 0.7 | 6.2 |

[c]PCB denotes polychlorinated biphenyls.

Table 1 (Continued). DUWAMISH ESTUARY ANNUAL POLLUTANT INPUTS FOR DOCUMENTED SOURCES (1970-1980) (From Harper-Owes, 1983).

| | INPUTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameters (Units) | Upstream Green River | Renton Treatment Plant | Black River | Combined Sewer Overflow | Regional Stormwater | Direct Industrial Discharge | Atmospheric | Deep Alvection from Elliott Bay | Total Documented Inputs |
| Total Pesticides[d] (kg/yr) | ? | 2.5 | ? | 0.2 | 0.8 | ? | ? | ? | 3.5 |
| Total Selected PAH[e] (kg/yr) | ? | 1.0 | ? | 3.8 | ? | ? | ? | 4.1 | 8.9 |
| Naphthalene (kg/yr) | ? | 5.5 | ? | 4.5 | ? | ? | ? | 3.1 | 13. |
| Total Phthalates[f] (kg x $10^3$/yr) | ? | 2.4 | ? | 0.3 | ? | ? | ? | ? | 2.7 |
| Fecal Coliform ($10^{12}$ organisms/yr) | 1,400. | 18. | 300. | 8,700. | 59. | ? | ? | ? | 10,000. |

[d]Total pesticides refer to the sum of aldrin, chlordane, DDD, DDE, DDT, dieldrin, endrin, heptachlor, and heptachlor epoxide.

[e]PAH denotes polynuclear armotic hydrocarbons, and refers here to the sum of anthracene, benzo[a]anthracene, benzo[a]pyrene, chrysene, fluoranthene, fluorene, phenanthrene, and pyrene.

[f]Total phthalates refer to the sum of bis (2-othylhexyl) phthalate, butyl-benzyl phthalate, diethyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate.

Table 2. CONCENTRATIONS OF ELEMENTS IN PUGET SOUND SUSPENDED MATTER COLLECTED JULY 1979 PPM DRY WEIGHT (MEAN VALUES FROM DUPLICATE SAMPLES, UNCERTAINTIES OF APPROXIMATELY $\pm$ 20% FOR $\sigma$)[20]

| ELEMENT | Harbor Island | West Waterway |
|---|---|---|
| As | 37 | 44 |
| Br | 78 | 75 |
| Co | 7.5 | 14 |
| Cr | 52 | 88 |
| Cu | 179 | 208 |
| Eu | 0.52 | 0.94 |
| Mn | 1050 | 1090 |
| Ni | 39 | 44 |
| Pb | 338 | 448 |
| Rb | 33 | 39 |
| Sb | 3.8 | 9.8 |
| Se | 1.1 | 1.2 |
| Sr | 213 | 213 |
| V | 62 | 106 |
| Zn | 540 | 580 |

Table 3. CONCENTRATIONS OF AROMATIC HYDROCARBONS IN FILTERED WATER FROM NINE SAMPLING SITES IN PUGET SOUND, $\bar{x} \pm$ SE, PARTS PER TRILLION (PPTR) DRY WEIGHT SEDIMENT.[20]

| Compounds | Seattle HI | Seattle WW |
|---|---|---|
| Naphthalene | 30 ± 1 | 38 ± 1 |
| 2-MN | 4 ± 4 | 8 ± 9 |
| 1-MN | 3 ± 2 | 10 ± 1 |
| 2,6-DMN | 3 ± 3 | 2 ± 1 |
| 1,3-DMN | 3 ± 1 | 3 ± 0 |
| 2,3-DMN | <1 | <1 |
| 2,3,6-TMN | 5 ± 3 | 7 ± 1 |
| Fluorene | <1 | <1 |
| Phenanthrene | 13 ± 1 | 14 ± 2 |
| Anthracene | <1 | <1 |
| 1-MP | 59 ± 17 | 41 ± 0 |
| 2-MP | 34 ± 31 | 57 ± 19 |
| Fluoranthene | <1 | <1 |
| Pyrene | 12 ± 1 | 10 ± 1 |
| 1-Me Pyrene | <1 | <1 |
| B(a)A | <1 | <1 |
| Chrysene | <1 | <1 |
| TOTAL | 165 ± 18 | 190 ± 76 |

HI = Harbor Island; WW = West Waterway

Table 4. CONCENTRATIONS OF SATURATE HYDROCARBONS ASSOCIATED WITH SUSPENDED MATTER FROM NINE SAMPLING SITES IN PUGET SOUND, $\bar{x} \pm$ SE, PARTS PER MILLION (PPM) DRY WEIGHT SEDIMENT.[20]

| Compounds | Seattle HI | Seattle WW |
|---|---|---|
| $C_{13}$ | 0.2 ± 0.0 | 0.8 ± 0.2 |
| $C_{14}$ | 0.5 ± 0.0 | 0.7 ± 0.1 |
| $C_{15}$ | 0.9 ± 0.0 | 0.7 ± 0.1 |
| $C_{16}$ | 1.0 ± 0.0 | 0.7 ± 0.1 |
| $C_{17}$ | 1.8 ± 0.1 | 1.5 ± 0.2 |
| Pristane | 2.8 ± 0.0 | 3.2 ± 0.7 |
| $C_{18}$ | 1.3 ± 0.1 | 1.0 ± 0.2 |
| Phytane | 1.0 ± 0.1 | 0.9 ± 0.1 |
| $C_{19}$ | 1.6 ± 0.2 | 1.5 ± 0.5 |
| $C_{20}$ | 1.1 ± 0.1 | 1.2 ± 0.1 |
| $C_{21}$ | 1.1 ± 0.3 | 1.1 ± 0.7 |
| $C_{22}$ | 1.2 ± 0.8 | 0.7 ± 0.1 |
| $C_{23}$ | 0.9 ± 0.6 | 1.4 ± 0.8 |
| $C_{24}$ | 0.3 ± 0.0 | 0.5 ± 0.0 |
| TOTAL | 15.9 ± 2.2 | 15.7 ± 1.9 |

HI = Harbor Island; WW = West Waterway

Table 5. CONCENTRATIONS OF AROMATIC HYDROCARBONS ASSOCIATED WITH SUSPENDED MATTER FROM NINE SAMPLING SITES IN PUGET SOUND, $\bar{x} \pm$ SE, PARTS PER MILLION (PPM) DRY WEIGHT SEDIMENT.[20]

| Compounds | Seattle HI | Seattle WW |
|---|---|---|
| Naphthalene | 0.02 ± 0.01 | 0.03 ± 0.01 |
| 2-MN[2] | 0.02 ± 0.01 | 0.02 ± 0.00 |
| 1-MN | 0.01 ± 0.00 | 0.01 ± 0.01 |
| 2,6-DMN | 0.01 ± 0.01 | 0.01 ± 0.00 |
| 1,3-DMN | 0.01 ± 0.00 | 0.01 ± 0.00 |
| 2,3-DMN | 0.01 ± 0.00 | <0.01 |
| 2,3,6-TMN | 0.01 ± 0.00 | 0.02 ± 0.00 |
| Fluorene | 0.04 ± 0.06 | <0.01 |
| Phenanthrene | 0.14 ± 0.09 | 0.22 ± 0.04 |
| Anthracene | <0.01 | 0.08 ± 0.02 |
| 1-MP | 0.01 ± 0.01 | <0.01 |
| 2-MP | 0.01 ± 0.08 | 0.08 ± 0.03 |
| Fluoranthene | 0.25 ± 0.09 | 0.36 ± 0.11 |
| Pyrene | 0.21 ± 0.20 | 0.58 ± 0.21 |
| 1-Me-Pyrene | <0.01 | <0.01 |
| B(a)A | 0.03 ± 0.01 | 0.07 ± 0.02 |
| Chrysene | 0.05 ± 0.00 | 0.12 ± 0.04 |
| B(a)P | <0.01 | <0.01 |
| Perylene | <0.01 | <0.01 |
| TOTAL | 0.90 ± 0.15 | 1.6 ± 0.50 |

HI = Harbor Island; WW = West Waterway
[2]MN = methylnaphthalene, DMN = dimethylnaphthalene
TMN = trimethylnaphthalene, MP = methylphenanthrene
1-Me-Pyrene = 1-methylprene, B(a)A = benz(a)anthracene
B(a)P = benz(a)pyrene

Table 6. MEAN TOTAL POLYCHLORINATED BIPHENYL CONCENTRATIONS IN VARIOUS REGIONS OF PUGET SOUND.[22]

| Area | Water ng $L^{-1}$ | SPM ng $g^{-1}$ | Zooplankton ug (g of lipid)$^{-1}$ | Sediment ng $g^{-1}$ | Surface Film ng $L^{-1}$ |
|---|---|---|---|---|---|
| Duwamish River | 22 ± 13(60)[a] | 1770 ± 540(70) | | | 116 ± 101(5) |
| Elliott Bay | 5.4 ± 13(185) | 920 ± 200(87) | 6.8 ± 3.1(11) | 637 ± 830(4) | 98 ± 83(6) |
| Main Basin | 4.3(1) | 104 ± 31(3) | 5.9 ± 4.4(4) | | 12(1) |

[a]Values in parentheses are the number of data points.

Table 7. BULK SEDIMENT ANALYSES FROM THE CONTAMINATED SHOAL TO BE DREDGED.[34]

| Element | PPM, dry wt. | | PPB, dry wt. |
|---|---|---|---|
| Beryllium | 0.2 | Aceton | 494[1/] |
| Cadmium | 1.4 | Methylene Chloride | 805[2/] |
| Chromium | 35 | bis (2-ethylhexyl) phthalate | trace[3/] |
| Copper | 130 | Di-n-octyl phthalate | trace[4/] |
| Lead | 190 | Aldrin | 180 |
| Arsenic | 22 | heptachlor | 80 |
| Mercury | 0.31 | 4,4'-DDE | 30 |
| Nickel | 20 | 4,4'-DDD | 80 |
| Selenium | 0.4 | Alpha endosulfan | 30 |
| Silver | 1.5 | endrin aldehyde | 30 |
| Zinc | 240 | | |

blank, ppb:8.7[1/]; 10.4[2/]; L/1,000[3/4/].

Appendix A, Figure 1

Concentrations of Selected Trace Metals
Observed in the Sediments of the Duwamish River

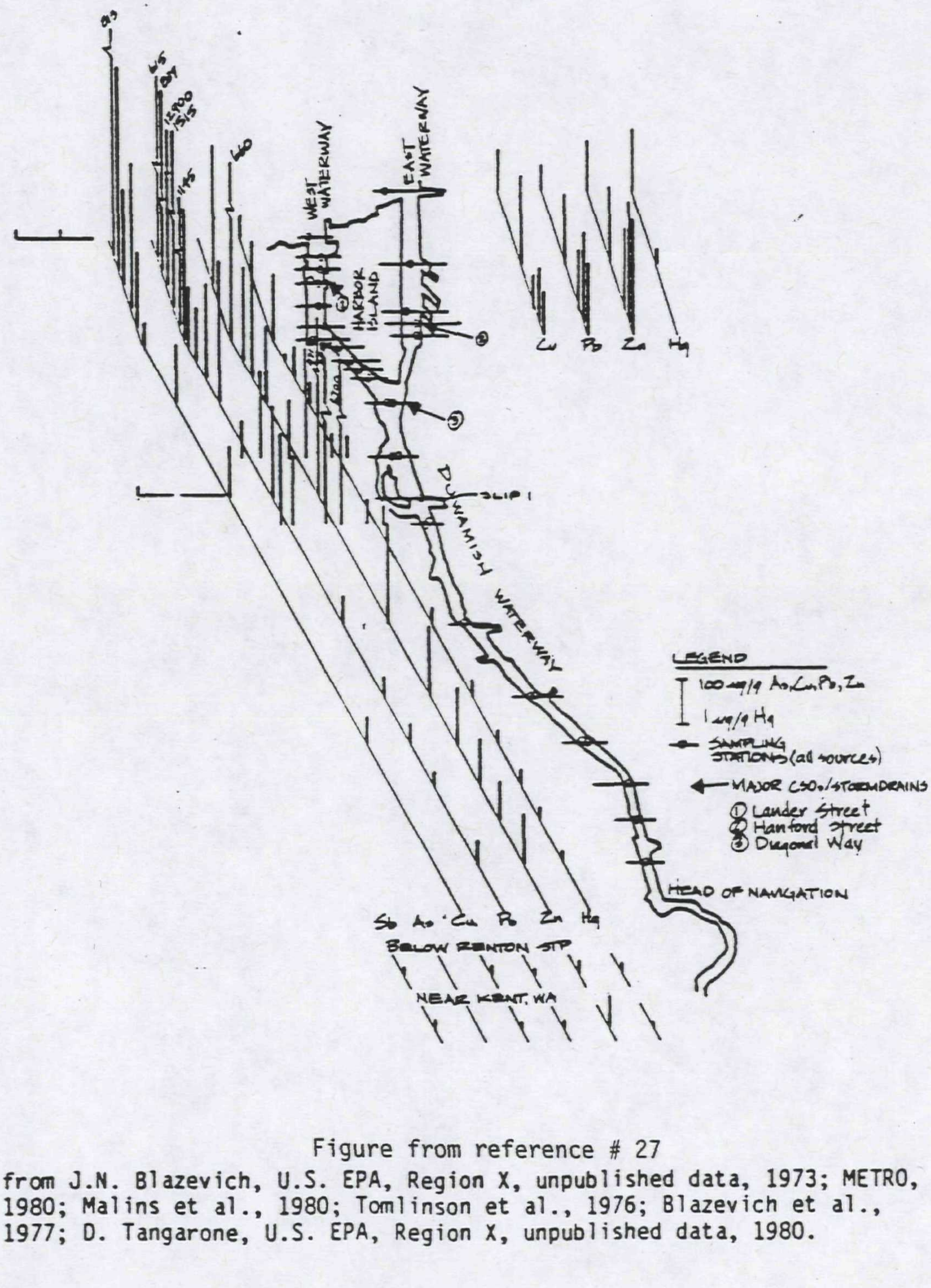



Figure from reference # 27

Data from J.N. Blazevich, U.S. EPA, Region X, unpublished data, 1973; METRO, 1980; Malins et al., 1980; Tomlinson et al., 1976; Blazevich et al., 1977; D. Tangarone, U.S. EPA, Region X, unpublished data, 1980.

# Appendix A, Figure 2

Concentrations of Selected Trace Metals
Observed in the Sediments of Elliott Bay

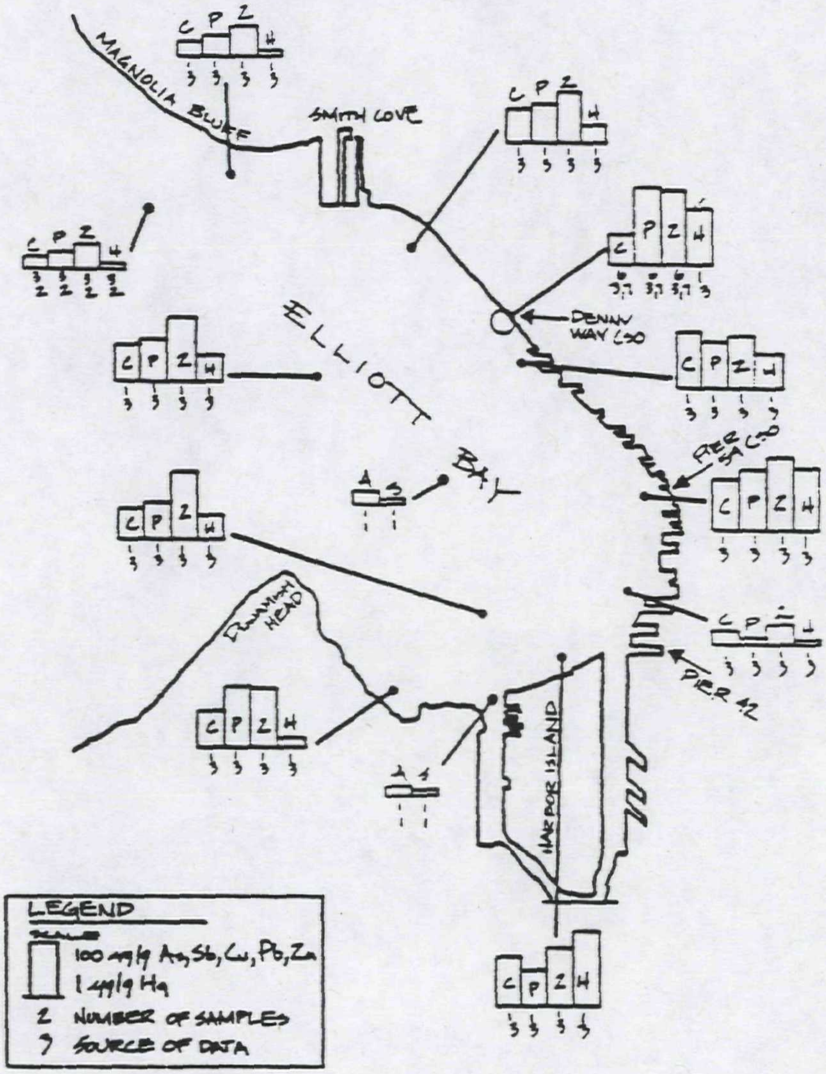
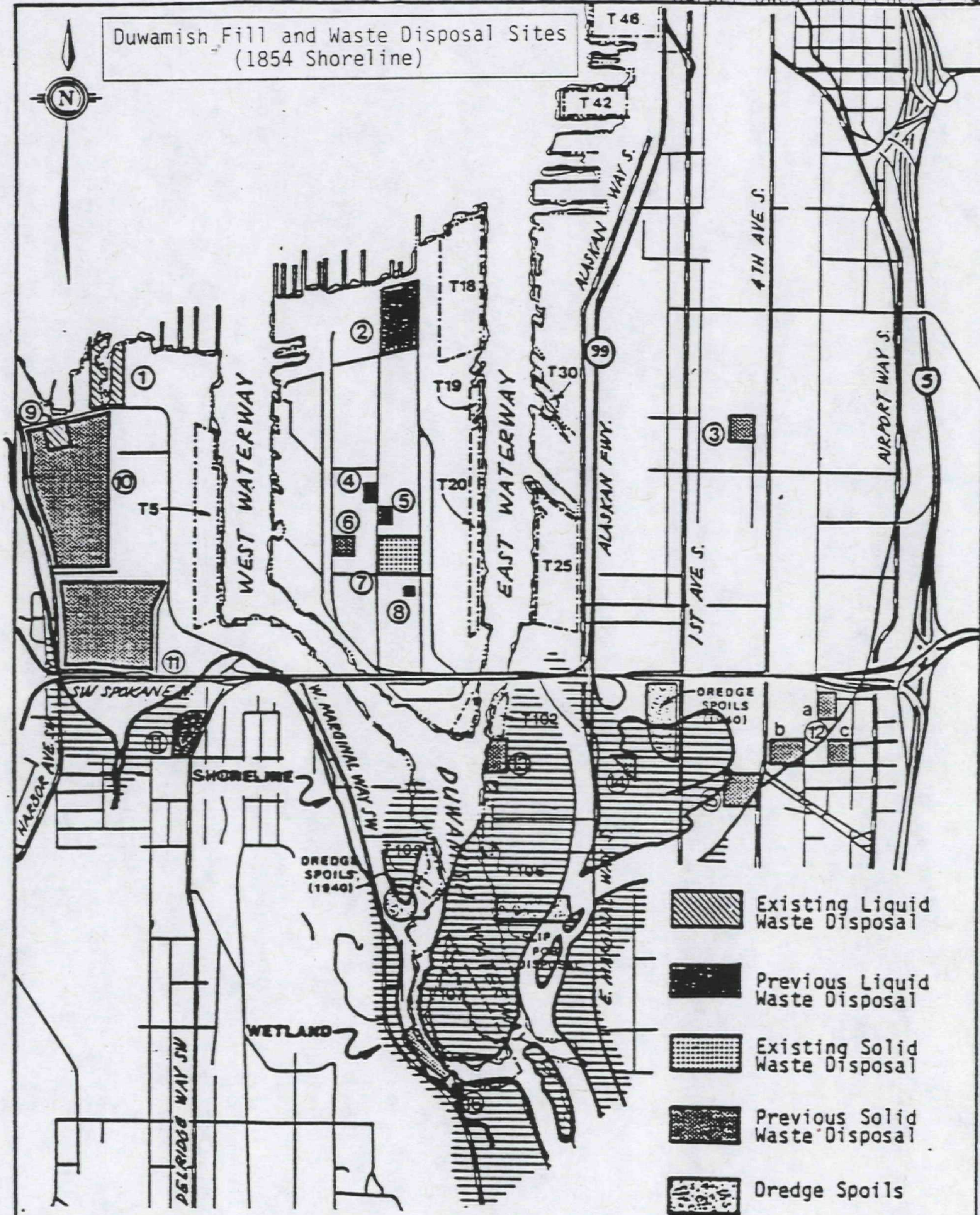



Figure from reference # 27
Data from 1) Crecelius et al., 1975; 2) Schell et al., 1976; 3) Malins et al., 1980; 7) Tomlinson et al., 1976.



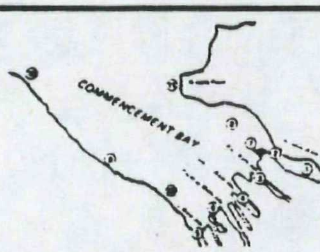

Adapted From:
Bartleson, G.C., M.J. Chrzatowski and A.K. Helgerson, 1980. Historical Changes in Shoreline and Wetland at Eleven Major Deltas in the Puget Sound Region, Washington. U.S. Geological Survey.

# Appendix A, Figure 4

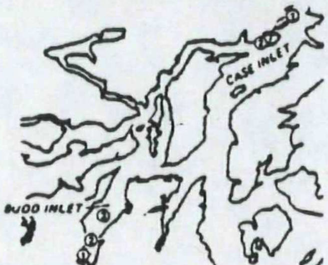
Concentrations in ug/g dry weight (ppm), of
Selected Metals in Sediments from Central Puget Sound.


| Source of Sediment Sample | Ag | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Se |
|---|---|---|---|---|---|---|---|---|---|---|
| | Element | | | | | | | | | |
| 1 Midway from Pt. Monroe to Pt. Jefferson | 2.0 | - | 6.2 | 46 | 26 | .11 | 340 | 42 | 20 | 22 |
| 2 Indianola, southwest | 1.5 | - | 3.1 | 23 | 10 | .04 | 200 | 22 | 10 | - |

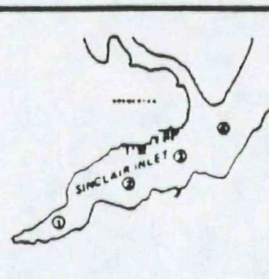

| Source of Sediment Sample | Ag | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Se |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Duwamish Waterway, near lumber mill | 3.0 | 95 | 12 | 45 | 130 | .38 | 420 | 36 | 260 | 80 |
| 2 Duwamish Waterway, west channel | 2.6 | 84 | 11 | 64 | 210 | .80 | 440 | 39 | 630 | 70 |
| 3 Duwamish Waterway, east channel | 3.3 | 280 | 18 | 49 | 110 | .35 | 570 | 46 | 160 | 113 |
| 4 Harbor Island, north end | 1.9 | - | 5.7 | 31 | 90 | 1.4 | 270 | 24 | 61 | - |
| 5 Pier 54 | 3.9 | - | 8.6 | 54 | 91 | 1.2 | 390 | 56 | 110 | 34 |
| 6 Pier 70 | 3.5 | - | 7.0 | 54 | 140 | .63 | 360 | 50 | 89 | 28 |
| 7 Midway from Pier 91 to Duwamish Head | 2.7 | - | 8.2 | 51 | 69 | .45 | 470 | 45 | 78 | 39 |
| 8 North of Pier 71 | 3.8 | - | 6.5 | 54 | 59 | 1.1 | 320 | 53 | 74 | 25 |
| 9 Magnolia Bluff | 1.3 | - | 4.5 | 28 | 24 | .10 | 320 | 25 | 37 | - |
| 10 Duwamish Head, southeast side | 2.0 | - | 7.3 | 70 | 61 | .15 | 590 | 55 | 110 | 23 |
| 11 Alki Point, south side | 1.2 | - | 3.8 | 28 | 10 | .03 | 350 | 35 | 13 | - |
| 12 West Point, north side | 1.4 | - | 4.7 | 37 | 19 | .10 | 240 | 42 | 16 | - |
| 13 Pier 42 | 1.6 | - | 4.6 | 40 | 23 | .03 | 300 | 47 | 8.2 | - |
| 14 Corps dump site | 2.2 | - | 6.5 | 39 | 60 | .42 | 380 | 30 | 65 | 26 |
| 15 Pier 86 | 3.2 | - | 7.4 | 54 | 64 | .36 | 480 | 58 | 73 | 30 |
| 16 Duwamish Waterway, 14th Ave. bridge | 2.1 | - | 8.3 | 36 | 54 | .25 | 280 | 30 | 40 | 40 |




| Source of Sediment Sample | Ag | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Se |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Hylebos waterway, lower turning basin | 2.9 | - | 9.6 | 48 | 260 | .79 | 260 | 64 | 150 | 34 |
| 2 Hylebos waterway, E. 11th St. Bridge | 2.4 | - | 6.8 | 34 | 85 | .43 | 200 | 42 | 110 | 27 |
| 3 Blair Waterway, E. 11th St. Bridge | 2.1 | - | 5.4 | 28 | 60 | .13 | 170 | 21 | 42 | - |
| 4 Sitcum Waterway | 11 | 470 | 16 | 59 | 1600 | .49 | 180 | 36 | 790 | 23 |
| 5 City Waterway | 5.0 | - | 9.1 | 47 | 180 | 1.0 | 190 | 33 | 270 | 23 |
| 6 Puyallup disposal site | 1.9 | - | 5.2 | 26 | 34 | .065 | 140 | 19 | 14 | - |
| 7 Between Hylebos and Blair | 2.2 | - | 5.6 | 27 | 51 | .11 | 190 | 23 | 29 | - |
| 8 Brown's Point, south side | 2.4 | - | 6.0 | 28 | 65 | .17 | 220 | 24 | 40 | 23 |
| 9 Creek at sewage plant | 1.9 | - | 4.2 | 31 | 43 | .10 | 320 | 29 | 29 | - |
| 10 Tacoma Yacht Club | 2.2 | - | 5.8 | 36 | 110 | .26 | 880 | 38 | 65 | - |
| 11 Brown's Point | 2.0 | - | 4.7 | 26 | 23 | .063 | 210 | 22 | 18 | - |
| 12 Hylebos Waterway, outside, to NW | 2.5 | - | 6.1 | 29 | 78 | .20 | 170 | 25 | 50 | 23 |
| 13 Old Tacoma | 2.5 | - | 5.6 | 29 | 130 | .34 | 240 | 25 | 170 | 22 |
| 14 Blair waterway, turning basin | 2.2 | - | 6.0 | 30 | 70 | .16 | 140 | 22 | 49 | - |




| Source of Sediment Sample | Ag | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Se |
|---|---|---|---|---|---|---|---|---|---|---|
| **Case Inlet:** | | | | | | | | | | |
| 1 Reach Island | 2.3 | - | 7.6 | 53 | 45 | .12 | 300 | 47 | 24 | 28 |
| 2 Stretch Island | 1.8 | - | 3.2 | 21 | 10 | .02 | 190 | 19 | 7.9 | - |
| **Budd Inlet:** | | | | | | | | | | |
| 1 Entrance channel, south end | 3.7 | 140 | 11 | 49 | 81 | .33 | 230 | 48 | 60 | 74 |
| 2 Priest Point | 2.7 | - | 8.2 | 35 | 37 | .12 | 180 | 35 | 23 | 28 |
| 3 Olympia Shoal | 3.0 | 57 | 9.5 | 50 | 70 | .28 | 230 | 45 | 49 | 59 |




| Source of Sediment Sample | Ag | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Se |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Southwest end | 4.8 | - | 8.1 | 72 | 150 | 1.1 | 300 | 51 | 98 | 30 |
| 2 Drydock area | 3.4 | - | 7.7 | 65 | 180 | 1.0 | 350 | 53 | 140 | 30 |
| 3 Point Turner, southwest side | 2.9 | - | 7.1 | 57 | 130 | 1.2 | 310 | 48 | 120 | 27 |
| 4 Point Herron, south side | 2.0 | - | 5.2 | 39 | 47 | .32 | 330 | 36 | 44 | - |

Figure taken from reference #39